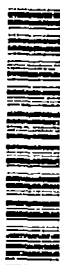


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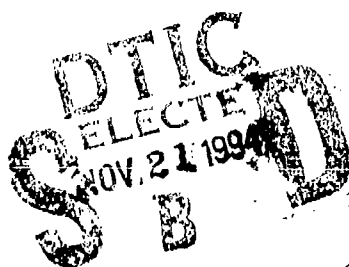


USERS GUIDE FOR THE SINGLE-STATION NOWCAST ANALYSIS PROGRAM

Jeffrey E. Passner

ARL-TR-262

April 1994



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13. ABSTRACT (Maximum 200 words) The U.S. Army Research Laboratory (ARL) has developed several weather related tactical decision aids (TDAs) to assist the battlefield commander. These TDAs are automated techniques and procedures that evaluate the significant effects of the current and forecasted weather. One of these TDAs is the single-station nowcast analysis package (SSNAP), which is a preliminary effort towards assisting the staff weather officer in making accurate and expeditious weather forecasts using only weather data from one single station. Data output from SSNAP includes a graphical representation of the skew T - log P thermodynamic diagram, icing and wind profiles, and D-Values. A chart of stability indices and many other important meteorological elements are also accessible to the user. As a final step in the prediction of short-term weather events, these data from SSNAP are passed to the ARL thunderstorm intelligence prediction system where they are used to predict the occurrence/nonoccurrence of both thunderstorms and severe thunderstorms.				
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1. INTRODUCTION

Weather observations, weather analyses, and weather forecasting greatly benefit the commander in properly interpreting the battlefield environment (Scheinartz et al. 1990). Improvement in analyzing and forecasting the weather means superior information is made available to the commander regarding current and future weather events that might alter military planning and operations. These weather observations can be used to create tactical decision aids (TDAs) that include assessing electro-optical sensor performance, smoke screen deployment effectiveness, and other operations that are affected by weather. Scheinhartz and Lee (1988) discuss the use of TDAs on PC compatible microcomputers.

Satellite imagery, radar, wind profilers, and other technologically advanced methods of observing the atmosphere can furnish nowcasts or short-term weather forecasts. When not engaged in combat, these weather observations are often easily attained and support the meteorologist along with the aid of some diagnostic models to make a nowcast. With the onset of conflict and primarily as the level of intensity expands, such weather observations may become scarce or will be eliminated. With this theory in mind, a sounding analysis program was formulated by the U.S. Army Atmospheric Sciences Laboratory (currently the Battlefield Environment Directorate, U.S. Army Research Laboratory (ARL)) to assist the staff weather officer (SWO) and the battlefield commander.

This report is divided into the following sections, each with a different degree of detail.

Section 1— Introduction

Section 2— How to initiate and run the single-station nowcast analysis package (SSNAP) on your computer

Section 3— Understanding the sounding data. How to decode the TTAA, TTBB, and PPBB data

Section 4— Data input methods into SSNAP

Section 5— Output options. The skew T - log P charts and weather data to assist the forecaster

Section 6— Thunderstorm Intelligence Prediction System (TIPS). How to use the expert system that predicts thunderstorms and severe weather

Section 7— Sounding analysis techniques. The equations that are used in the program and a summary of thunderstorm forecasting

Section 8— Summary of how SSNAP runs and a general overview of the menus and their options

2. HOW TO INITIATE AND RUN SSNAP ON YOUR COMPUTER

2.1 Hardware Required to Run the Program

- PC compatible computer
- MS-DOS environment (Version 3.2 or later)
- 3-1/2 in or 5-1/4 in floppy drive
- EGA graphics

2.2 Program Installation

- Use either the 3-1/2 in or 5-1/4 in floppy disk from ARL.
- You can run SSNAP from the disk drive or copy the run-time files onto the hard drive on the PC.
- First, verify that the files needed to run the program are on the disk that you receive from ARL. The disk should contain several files with executable (.exe) and data (.dat) extensions. There should be a few meteorological data files such as 05209212.tta and 05209212.ttb that contain TTAA, TTEB, and PPBB data. Some files will have .arc extensions that contain archived weather data. There should be in excess of 30 files on your disk. If the number of files is vastly different (such as 0 or 300), please call.... This difference means we made an error and your sounding analysis package probably will not run.
- Use your MS-DOS commands to copy the data from the floppy disk to the hard drive if you wish.
- Once you have gathered all the files on the disk or hard drive, "install" the program. This step is extremely important. Type the word STARTME (no quotes needed) to generate the installation procedure.
- Refer to the Install SSNAP menu on your screen.

```
-----Install SSNAP-----  
| eXit to MS-DOS |  
| Specify Colors |  
| Specify Unit and Classification |  
| Specify Directories |  
----- Select or ? for Help -----
```

Select Specify Directories from this menu, which is the important choice here. Move the cursor (or mouse) to the selection and another menu will appear.

- Determine from this menu where the files will be stored or what drives and directories will be used.

```

—Drive and Directory Installation Options—
| Return to Previous menu                |
| Driver Directory                      |
| Data Directory                       |
| Program Directory                    |
|_____ Select or ? for Help _____|

```

We recommend placing all the files in the same directory or subdirectory when you copy them over from the original floppy; however, to arrange the files in different directories, use the on-line help.

- Select the Driver Directory from this menu. Place the drive in the directory/subdirectory from which you wish to "drive" the program. As an example below, place all the files on the C drive in a directory called "Weather" (do not place quotes around the name of the directory). Type the backslash after the name of the directory.

Enter Driver Directory: C:\Weather_____

- Select the Data Directory, which is where the meteorological sounding data is stored.

Enter Data Directory: C:\Weather_____

- Select the program directory.

Enter Program Directory: C:\Weather_____

- Return to the previous menu here.
- When no further changes are needed in the directories or in the colors, exit back to MS-DOS.
- Now start using the sounding analysis program. Type SSNAP and the data input menu should appear.

3. THE SOUNDING DATA

The only data being used in SSNAP now is a radiosonde report in World Meteorological Organization (WMO) format (*Federal Meteorological Handbook No. 4*, 1976). Rawinsonde observations (RAOBS) examine the pressure, temperature, humidity, and wind structure from the earth's surface to where the balloon bursts. The radiosonde consists of meteorological measuring elements coupled to a radio transmitter and assembled into a small lightweight box. The device is carried aloft by balloons filled with hydrogen or sometimes helium gas. As this balloon rises, measurements of pressure, temperature, and humidity are transmitted to a ground station where data are recorded automatically. An observer then transcribes the information into a code that is most commonly divided into different groups known as the TTAAs (mandatory levels), the TTBBs (significant level temperatures), and the PPBBs (significant level winds). Pressure is measured in millibars, temperature and dew-point readings in degrees Celsius, wind direction in degrees between 0° and 360°, and windspeed in knots.

Mandatory levels are the levels that must be included in each rawinsonde release. These mandatory levels are as follows: Surface level, 1000, 925, 850, 700, 500, 400, 300, 250, 150, and 100 mbar. The mandatory data also includes information about the tropopause level and the level of maximum windspeed in the sounding.

The significant temperature levels are often areas in the atmosphere where changes in the temperature or moisture are considered "important." They are determined by changes in the linearity in the lapse rate of temperature and dew point. Usually these are levels where inversions of the temperature are noted or levels where there are fluctuations in the moisture profile.

The significant level winds are grouped in thousands of feet and are coded in a manner where the data is initiated at the surface and continues to a height level slightly over 50,000 ft above ground level. Below is an example of how a typical rawinsonde might appear after it has been received from a data source.

```
TTAA 65121 72357 99966 18619 17010 00053 ///// ///// 92728 21804
19037 85465 20645 21521 70125 10065 25010 50583 07780 27020 40752
20780 26025 30958 37580 29039 25082 467// 28574 20226 571// 28573
15403 669// 27069 10650 675// 25540 88153 671// 27071 77218 28100
43032-
```

```
TTBB 65120 72357 00966 18619 11938 18809 22925 21804 33910 23015
44863 20218 55833 23473 66828 23880 77658 04860 88650 04466
99638 06080 11359 26180 22286 40180-
PPBB 65120 72357 90023 17010 18038 20035 90467 21028 23012 23012
91124 25512 24514 22015 9167/ 26015 27019 92025 27018 28025 26029
95012 26551 26536 24527-
```

This data is from Norman, Oklahoma, at 1200 universal time coordinates (UTC) on 15 June 1992.

Two groups of data are shown here—the upper group is the TTAA data and the lower group is the combined data from the TTBB and PPBB group. If ingesting data from a commercial system, anticipate data such as this or in some combination of the TTAAs, TTBBs, and PPBBs. For this sounding analysis program, data above 100 mbar is not necessary; thus, TTCC, TTDD, or PPDD data is not needed.

3.1 Decoding the TTAA Data

The standard code for the TTAA data is as follows:

```
TTAA YYGGI IIIII 99PPP TTTDD dffff 00hhh TTTDD dffff 92hhh TTTDD dffff
85hhh
TTTDD dffff 70hhh TTTDD dffff 50hhh TTTDD dffff 40hhh TTTDD dffff
30hhh TTTDD dffff 25hhh TTTDD dffff 20hhh TTTDD dffff
15hhh TTTDD dffff 10hhh TTTDD dffff 88PPP TTTDD dffff 77PPP
dffff.
```

The first item in the code is the group label, in this case TTAA. The YYGGI group is the date-time group. The YY symbol represents the date.

The code was constructed so that 50 must be subtracted from the value to get the current date. In the case above, the YY value is 65; therefore, subtract 50 to get the current day of the month—15. Note that there is no way to identify the month that the data originated from. Since SSNAP allows you to save the decoded sounding data (section 5.10), group data from individual months in different files or on separate floppy disks. The time of the rawinsonde is placed next to the date and is represented by the GG code. In this case, the Norman sounding, the release time is recorded as 12 or 1200 UTC. Typically, most stations do their upper observations twice a day, at 1200 and 0000 UTC. (The actual balloon release is about an hour before the data appears.) However, many military locations or special stations will release an RAOB at times other than the standard 1200 and 0000 UTC. The last letter in the YYGGI group is the I. This stands for the level to which the wind data is available. In the TTAA data above, the value of I is 1; thus the wind data is available to 100 mbar.

1 - wind data available to 100 mbar

4 - data available to 400 mbar

8 - data available to 850 mbar

The IIII group refers to the five-number ID for the station. The II represents the block number, which is typically 72 for most of the stations in the continental United States (Chatam, Massachusetts, is an exception; their block number is 74). The iii group is the actual station identifier, which is 357 for Norman, Oklahoma.

The next group is the 99 group, which is the surface data identifier. The next three blocks will involve data from the surface. In the Norman case the 99PPP TTDD dffff group is represented by 99966 18619 17010. Note that in some references the dffff group is coded as dddff; the meaning of each is the same. The first numbers following 99 are the surface pressure readings in millibars. In this case the pressure at the surface is 966 mbar. Often the pressure at the surface is near 1000.0 mbar. Understand that when the first digit is a 0, add a 1 to get the pressure. When the first digit is a 9, read the surface pressure as the data indicates. Below are some examples:

99966 - Pressure at surface is 966 mbar

99014 - Pressure at surface is 1014 mbar

99875 - Pressure at surface is 875 mbar (this is a station at nearly 4,000 ft mean sea level (MSL))

99993 - Pressure at surface is 993 mbar

99018 - Pressure at surface is 1018 mbar

The remainder of the 99 group gives surface temperature, dew point, and wind data. In our example the next block reads 18619. Negative values are not allowed in the rawinsonde code, which could be a problem. Thus, to differentiate between positive and negative values the third value of TTT indicates whether a value is positive or negative reading. For example, at 500 mbar the temperature is almost always below zero. Thus, in the code you will see values such as 181, 183, 185, 187, and 189. Since the final digit is an odd number, these temperatures are interpreted

as -18.1, -18.3, -18.5, -18.7, and -18.9. Conversely, when the final digit is an even number, the temperature is positive. The following examples will help one understand these ideas.

Examples (all temperatures are in degrees Celsius):

TTT - value
 001 - -0.1 °C
 000 - 0.0 °C
 002 - +0.2 °C
 186 - +18.6 °C
 148 - +14.8 °C
 029 - -2.9 °C
 563 - -56.3 °C
 320 - +32.0 °C

The dew-point values are the DD part of the TTTDD block. However, the dew point is actually reported as the dew-point depression from the temperature value at the surface, or for whatever level TTTDD is reported. In our example in the Norman, Oklahoma, sounding the TTTDD block at the surface reads 18619. The temperature is +18.6 and the dew-point depression is read as 1.9. This means the dew point is 16.7 °C at the surface. A few rules that should be recalled when decoding dew-point depression are the following:

- When the dew-point depression is 5 °C or less, the units and tenths figures are reported.
- When the dew-point depression code is more than 55, the dew-point depression is reached by subtracting 50.
- The values between 51 and 55 are not used.

Examples

<u>Depression Code</u>	<u>Dew-Point Depression °C</u>
01	0.1
12	1.2
32	3.2
49	4.9
50	5.0
51-55 are not used	
56	6 (56 - 50 = 6)
66	16 (66 - 50 = 16)
71	21 (71 - 50 = 21)
80	30 or more (80 - 50 = 30)

Typically, when the upper atmosphere is very dry, the depression will often be recorded as 80. Once the RAOB ascends past 300 mbar, the dew-point depression is not often recorded since there is little moisture at the highest levels of the troposphere. This data will be reported as two slashes (/ /).

The ddfff group is the wind data. At the surface in our Norman sounding this group is 17010, meaning the wind is blowing from 170° at 10 kn. The dd part is the wind direction from 0° to 360°. In the fff part of this group only one "trick" occurs when the windspeed in the atmosphere is in excess of 100 kn. If the windspeed exceeds 100 kn, note that a value of 1 has been added to the total wind direction angle. Below are some examples.

Examples:

<u>Code</u>	<u>Wind Direction</u> <u>(°)</u>	<u>Windspeed</u> <u>(kn)</u>
04012	040	12
13503	135	3
27065	270	65
29595	295	95
34605	345	105
34115	340	115
29662	295	162
00000	calm winds	

The next three blocks in the TTAA data are at the 1000-mbar level. This will start the sequence of groups that include the mandatory levels, their heights, temperatures, dew-point depressions, and wind data. At many stations, 1000 mbar will be below the surface pressure level, and in this case it is impossible to have a temperature (TTTDD) group or wind group (ddfff). Our Norman sounding shows the symbols 00053 ///// /////. The first two symbols (00) indicate that this is the 1000-mbar group, and 053 indicates the height in meters. This value is reached by reduction to sea level. The TTTDD and DDFFF groups are slashed out since there is obviously no temperature, dew-point depression, or wind data below the surface. The next level is the 925-mbar level, which has been added to the mandatory level data in an effort to provide more information about the weather conditions near the surface. At 925 mbar the three data blocks are 92728 21804 19037. Another rule of thumb is that for all heights below 500 mbar the height is read in whole meters. Above and including 500 mbar, the heights are recorded in tens of meters. With experience one will learn to interpret the height values with each mandatory level. Below is a listing of approximate values of the heights at a few mandatory levels.

Example:

<u>Pressure</u> <u>(mbar)</u>	<u>Average Height</u> <u>(m)</u>
850	1500
700	3000
500	5500
400	7500
300	9500

In the example above, using the Norman data, the height at 925 mbar is 728 m above the ground. The temperature is 21.8° while the dew-point depression is 0.4°. Winds are from 190° at 37 kn.

The next level is the 850-mbar level as indicated by the next three blocks, which read 85465 20645 21521. In our Norman example, the 850 mbar is read as 1465 m above sea level. The temperature at 850 mbar is 20.6 and the dew-point depression is 4.5. The winds at 850 mbar are recorded here as 21521, meaning that the wind is from 215° at 21 kn. The next level in the mandatory levels is at 700 mbar. The height is recorded as 70125, meaning 3125 m in this case. At 700 mbar, when the height is a smaller number such as 125 in this case, this means that the first digit is a 3. When the value is a larger value such as 980, this will mean the first digit is a 2 and the height at 700 mbar is 2980 m. The remaining values at 700 mbar are read as previously described—70125 10065 25010. The temperature is +10.0 and the dew-point depression is 65-50 or 15°. The wind is from 250° at 10 kn. At 500 mbar the block reads 50583 07783 27020. The height is 5830 m, the temperature is -7.7, and the depression of the dew point is 30. The wind is from 270° at 20 kn. At 400 mbar, the next mandatory level is introduced. The code says 40752 20780 26025. The height is 7520 m. The temperature is -20.7 °C with a dew-point depression of 30. The wind at 400 mbar is from 260° at 25 kn. Below is an interpretation of the entire TTAA block.

<u>Pressure</u> <u>(mbar)</u>	<u>Height</u> <u>(m)</u>	<u>Temp</u> <u>(°C)</u>	<u>DD</u> <u>(°C)</u>	<u>Wind Dir</u> <u>(deg)</u>	<u>Windspeed</u> <u>(kn)</u>
966	Surface	18.6	1.9	170	10
1000	053	////	///	///	//
925	728	21.8	0.4	190	37
850	1465	20.6	4.5	215	21
700	3125	10.0	15.0	250	10
500	5830	- 7.7	30.0	270	20
400	7520	-20.7	30.0	260	25
300	9580	-37.5	30.0	290	39
250	10820	-46.7	////	285	74
200	12260	-57.1	////	285	73
150	14030	-66.9	////	270	69
100	16650	-67.5	////	255	40

The last two bits of information are the 88 group (tropopause data) and the 77 group (the level of maximum winds). In the Norman sounding we read 88153 671// 27071. The code reads as 88PPP TTDD DDFFF. The pressure of the tropopause is 153 mbar with a temperature of -67.1 °C. The wind is from 270° at 71 kn. The 77 group is written as 77PPP DDFFF. This is recorded in our Norman sounding as 77218 28100. Thus the level of maximum winds is at 218 mbar and the wind at the level is from 280° at 100 kn. The data that is recorded after the 77PPP DDFFF group is not relevant for the SSNAP program.

3.2 Decoding the TTBB Data

The decoding of the TTAA data may be challenging if this data has not been used previously. Fortunately, the mechanisms to decipher the TTBB data are less complex. The format used in decoding the TTBB or significant temperature level data is as follows.

TTBB YYGG/ IIIII OOPPP TTTDD 11PPP TTTDD 22PPP TTTDD 33PPP TTTDD
44PPP TTTDD 55PPP TTTDD 66PPP TTTDD 77PPP TTTDD 88PPP TTTDD 99PPP
TTTDD 11PPP TTTDD 22PPP TTTDD....

The TTBB data for Norman, Oklahoma, on 15 June 1992 appears below.

TTBB 65120 72357 00966 18619 11938 18809 22925 21804 33910 23015 44863
20218 55833 23473 66828 23880 77658 04860 88650 04466 99638 06680 11359
26180 22286 40180

The first block identifies which group has been received. TTBB means that this is the significant temperature level data. The YYGG/group shows the date and time. In our sounding above, the YYGG/group reads as 65120. To get the date, subtract 50 from the value listed, $65 - 50 = 15$, which indicates the data is for the fifteenth day of the month. The time is again 1200 UTC.

The IIIII group is the station five-number identifier, 72357. The remainder of the TTBB follows a distinct pattern. The 00 group represents the surface data. Thus OOPPP TTTDD is recorded at Norman as 00966 18619. This means that the pressure in millibars at the surface is 966. The surface temperature is $+18.6^{\circ}\text{C}$ with a dew-point depression of 1.9°C .

The next group reads 11PPP TTTDD. Note that each group leader is a multiple of 11. The pattern of each group is in a pattern of 11, 22, 33, 44, 55, 66, 77, 88, 99, 11. To underline each multiple of 11 might help the user understand where the xxPPP TTTDD begins and ends. Again, the data being received in the TTBB group is called "significant level data," which means that something is happening in either the temperature or moisture profile that needs to be addressed. In our Norman sounding the 11PPP TTTDD group is reported as 11938 18809. This means that at 938 mbar the temperature is 18.8°C with a dew-point depression of 0.9°C . The next group is the 22PPP TTTDD group. Our data reads 22925 21804. Thus the pressure level is 925 mbar, the temperature is 21.8°C , and the dew-point depression is 0.4° . Notice that the temperature at 925 mbar (21.8°C) is warmer than the temperature at 938 mbar (18.8°C). This increase in temperature with height indicates that an inversion in the temperature profile exists. The data continues with the next group as 33910 23015. At 910 mbar the temperature is 23.0°C and the dew-point depression is 1.5°C . The TTBB data continues to as high as 100 mbar; however, there is no set number of levels received in this data group. On certain days there may be only a few significant levels, and on other days there may be as many as 20 or 30 different blocks in the TTBB group. The following table shows the values for the TTBB data at Norman. Note that the higher levels of the TTTDD group may appear as 40180, meaning that dew-point depressions cannot be measured (80-50-30). There is no wind data in the TTBB data; that information is available in the PPBB group.

<u>Pressure</u> <u>(mbar)</u>	<u>Temperature</u> <u>(°C)</u>	<u>Dew-Point Depression</u> <u>(°C)</u>
966	18.6	1.9
938	18.8	0.9
925	21.8	0.4
910	23.0	1.5
863	20.2	1.8
833	23.4	23.0
828	23.8	30.0
658	4.8	10.0
650	4.4	16.0
638	6.6	30.0
359	-26.1	30.0
286	-40.1	30.0

3.3 Decoding the PPBB Data

The significant level wind data provides a detailed look at the wind profile in the atmosphere. There are four blocks in each wind group.

PPBB YYGGa IIII 9tuuu dffff dffff dffff 9tuuu dffff dffff 9tuuu
dffff dffff....

Data for Norman, Oklahoma, on 15 June 1992 is below.

PPBB 65120 72357 90023 17010 18038 20035 90467 21028 23012 23012
91124 25512 24514 22015 9167/ 26015 27019 92025 27018 28025
26029 95012 26551 26536 24527-

The first block shows that this is the PPBB block. Again the data contains the YYGGa group, where the YY is the day of the month and the GG value is the time release of the rawinsonde. The small "a" that is the fifth value of this group is the coded indicator for type of wind instrument equipment. This is not very important for the applications here; however, a 0 is the digit that appears most frequently. In our Norman sounding the YYGGa group reads 65120. Thus the day of the month is 65 - 50 - 15, and the time is 1200 UTC. The wind measurement digit is a 0. The IIII group represents the station identifier and in this case the number is 72357.

The wind data is depicted in thousands of feet starting with the surface data. As an example, the 9tuuu dffff dffff dffff group that appears first at Norman reads as 90023 17010 18038 20035. Thus in this case, only two groups are available in the first block. The 90023 represents 9 as the code to indicate that a new block is starting, and 0023 means that the tens unit is 0 and the next 0 indicates that this is the surface wind. The 2 means that the second wind level available is at 2,000 ft above MSL, and the 3 means the next wind level is 3,000 ft. Thus, the surface wind is blowing from 170° at 10 kn. The wind at 2,000 ft is from 180° at 38 kn, while the final wind at 3,000 ft is from 200° at 35 kn.

The next group at Norman is 90467. There are wind readings to follow at 4,000, 6,000, and 7,000 ft MSL. The full block appears as 90467 21028 23012 23012. At 4,000 ft the wind is from 210° at 28 kn, at 6,000 ft the wind is blowing from 230° at 12 kn, and at 7,000 ft the wind is 230° at 12 kn. This pattern continues for the next 9tuuu group—91124 25512 24514 22015. Thus at 11,000 ft the wind is 255° at 12 kn, at 12,000 ft the wind is 245° at 14 kn, and at 14,000 ft the wind is from 220° at 15 kn. The appearance of a slash means that data is missing. Below is an interpretation of all the wind levels from the PPBB data set.

<u>Height (ft)</u>	<u>Wind Direction (deg)</u>	<u>Windspeed (kn)</u>
Surface	170	10
2,000	180	38
3,000	200	35
4,000	210	28
6,000	230	12
7,000	230	12
11,000	255	12
12,000	245	14
14,000	220	15
16,000	260	15
17,000	270	19
20,000	270	18
22,000	280	25
25,000	260	29
50,000	265	51
51,000	265	36
52,000	245	27

The actual number of levels will vary from rawinsonde to rawinsonde; however, typically, there will be wind readings from the surface to about 53,000 ft. Below is an overview of some of the more "tricky" aspects of reading the data. Remember, at a high elevation station such as Denver, the surface winds will be at a level over 5,000 ft MSL. Thus the opening group might appear as follows: 90067, with data for the surface, and then 6,000 and 7,000 ft MSL.

Example:

<u>Code</u>	<u>Winds</u>
90024 13006 13007 14509	Surface wind - 130° 6 kn 2,000 ft MSL - 130° 7 kn 4,000 ft MSL - 145° 9 kn
909// 17016	9,000 ft MSL - 170° 16 kn
9146/ 22019 23025	14,000 ft MSL - 220° 19 kn 16,000 ft MSL - 230° 25 kn

4. DATA INPUT INTO THE SSNAP

4.1 The SSNAP Data Input Menu

As instructed previously, at the prompt, type SSNAP (for single-station nowcast analysis program) to start the program and display the main input menu. The flow of the program is a circle, so after the program is started and a data input method is selected, the program will then process and format this data so that it can be used for the output options on the next menu. From the output options, the program can be exited or the thunderstorm expert system can be run.

Once a menu appears on the screen, select an option by moving the cursor or mouse to that selection. Hit RETURN if using the cursor control, press the left button if using the mouse, or type the highlighted letter on each line to select that option. The highlighted letter will materialize in a different color or will be capitalized.

In addition, on-line help is available for each option. Once a menu appears, if help is needed or if you want to review what functions are available for each option, hit a Shift ? combination and then select the option you need help with. The explanations will be brief and will mainly summarize what the option does.

Once you have typed SSNAP, the main input menu will be the first menu that appears. This menu consists mainly of different methods of ingesting data into SSNAP so that the final end products and the thunderstorm expert system can be used. Choosing the method of input is very significant since it must be compatible with the available data source. Mainly there are two choices; one will include having the data on a disk drive (hard disk or floppy) and the other will involve typing the data into SSNAP. During times of military conflict, the rawinsonde release will more likely be typed. Section 3 explains how the TTAA, TTBB, and PPBB codes are deciphered. The following table shows the SSNAP data input menu.

SSNAP Data Input Menu	
eXit to Thunderstorm Expert System Selection Menu	
Decode a Rawinsonde Report — RAOB Input at Keyboard	
Enter Decoded Data by Hand —Data Input at Keyboard	
Use Undecoded Rawinsonde Data Stored on Disk	
Retrieve a Sounding From a File	
Select or ? for Help	

The top selection is the X selection or "exit" choice. This selection allows you to exit from SSNAP into the Thunderstorm Expert System Selection Menu. As will be explained later, this menu will permit you to run the thunderstorm expert system or allow you to escape from SSNAP.

The middle group of choices lets you determine which method of data input is going to be used. The first method is attained by typing the letter D

or moving the cursor (or mouse) to this selection on the menu. Here you will type in the upper-air observation in traditional TTAA, TTBB, and PPBB formats. This option is fairly rigid in its application. Directions must be followed closely because the program is very sensitive to typing errors and inaccurate data. During times of military conflict or inadequate communications, this method of data ingest into SSNAP will probably be most useful. The program must have the TTAA data for best results; however, it will still run even if data is missing from some of the mandatory levels. In all cases, the surface level data must be placed into the program. WITHOUT SURFACE DATA THE PROGRAM WILL NOT BE ABLE TO RUN.

The second method of inputting data is the E option (Enter Decoded Data by Hand—Data Input at Keyboard). This method allows more freedom—in that the mandatory level data is not necessary for the program to run. However, for best results, you should have as many of the mandatory data levels as possible. Data can be input from any height level and will be incorporated into the program. Data limits are checked to make sure that the data is within legitimate limits for each variable.

The final method of data ingest is the U option (Use Undecoded Rawinsonde Data Stored on Disk). In this case, the data may be stored on the hard disk. Ingest the TTAA, TTBB, and PPBB data in raw form and store it on the same disk drive with SSNAP. Determine a method to receive the 0000 or 1200 UTC (or any other available times) data from rawinsonde stations. As an example, sounding data can be collected from the domestic data service of the Zephyr company, from other companies, or from artillery sources. Once the data is stored on the hard drive, a series of menus will lead you through this technique of running the program.

The final selection on the SSNAP main menu is the R option (Retrieve a Sounding From a File). Here instruct the program to retrieve either on the hard drive or on a floppy disk drive. This data has already been decoded using either the D, E, or U option earlier.

4.1.1 Decode a Rawinsonde Report--Data Input at Keyboard

The first method of entering new rawinsonde data requires typing a coded radiosonde report. This is the "D" option on the main input menu. The radiosonde code is displayed on the screen in symbols consisting of alphanumeric text. In this case, type in the TTAA data from 15 June 1992 at Norman, Oklahoma.

```
TTAA 65121 72357 99966 18619 17010 00053 ///// ///// 92728 21804
19037 85465 20645 21521 70125 10065 25010 50583 07780 27020 40752
20780 26025 30958 37580 29039 25082 467// 28574 20226 571// 28573
15403 669// 27069 10650 675// 25540 88153 671// 27071 77218 28100
43032-
```

First a TTAA page will appear that will require you to type in the station name being used (see example below). Type only the name of the station (for example "Norman")—do not type in the quotes. The program is coded such that it will search just for the station name (Norman) in the data base. An example of how to input the station name for TTAA data follows.

Mandatory Level Data—TTAA Group

Please type name of station, use the
Station name only. Do not use abbreviations

Or state names or state abbreviations.

Example.... Omaha should be typed

Not Omaha, NE or OMA, or Omaha, Nebraska

Name of Station Norman_____

If you choose a station that is not in the SSNAP data base, the resulting opening page will look different. As an example, if the station name White Sands Missile Range is typed and that station is not in the computer's storage, you will be asked to type the station elevation in meters. You will also be asked for the latitude and longitude of the station. If this information is not available or unknown, the program will still run. However some problems might appear later on in the program if the surface elevation (in meters) is unknown. Because this is very important data, please make an effort to know the elevation of the station. Even though you are allowed to type four digits for the elevation, if the surface elevation is 6 m, you need type only a 6. Type a period in the latitude and longitude values—for example, 32.21 is correct, not 3221 or 3221N. Degree symbols or any other symbols do not need to be typed after the number. The program does not care if the location is 32.21N or 32.21S—32.21 is sufficient.

Below is an example of a station that is not in the SSNAP data base.

Mandatory Level Data — TTAA Group

Please type name of station, use the
Station name only. Do not use abbreviations

Or state names or state abbreviations.

Example.... Omaha should be typed

Not Omaha, NE or OMA, or Omaha, Nebraska

Name of Station White Sands Missile Range

You have entered a Station Name that is not in the database

Please Enter the following information if possible

If you do not know the answers..hit return and continue

What is the Elevation (in meters) of the Station?

(User types here) 1224

What is the Latitude of the Station?

(User types here) 32.21

What is the Longitude of the Station?

(User types here) 106.22

Whether using a case where the station name is in the data base or not, you should use the same format for the remainder of the program. Below is the first set of data to be typed, the TTAA menu.

Mandatory Level Data — TTAA Group

Please type in the data over given characters.

The YYGGI group gives the date and time for TTAA

YY=date (Example 57 is 7th day of month)

GGI=Is the time and max height of TTAA
(Example 121, refers to 12Z and 100 mbar)
Input data in this form — TTAA YYGGI IIIII
Time group and station ID — TTAA YYGGI IIIII

First the YYGGI data will be input and then the IIIII group will be input. Again the YYGGI group gives the date of the sounding in a code. In the example below, the data for Norman, Oklahoma, on 15 June 1992 is typed in. Thus the YY value is 65 (50 + 15 = 65). The time of the sounding is 1200 UTC and that is typed in for the GG. The value typed in for I is 1 in this case. The IIIII is the five-number station identifier, which is 72357 for Norman. Hit the return key after each level is entered. The first level to enter is the surface level.

Input in this form PPP TTtDD dddff
Surface data — 99966 18619 17010

The 99 will already be typed so type the surface pressure (966 mbar), the TTtDD group (18619), and the dddff group (17010). Remember that the TTtDD group is the temperature and dew-point depression, while the dddff group gives the wind direction (in degrees) and windspeed (in knots). Also recall that in cases when the surface pressure is less than 1000 mbar, it will be impossible to have data for temperature and winds at the level, 1000 mbar. Missing data is typed as ///// for those two groups at 1000 mbar.

The next level that will appear is 92, which represents the 925-mbar level data. This process continues for all mandatory data up to and including 100 mbar. The 88 symbol is for the tropopause data and includes the temperature, dew-point depression, and wind data at that height. In this example 88153 671// 27071 has been typed. This means that the tropopause data is located at 153 mbar. The temperature is -67.1 °C and the dew-point depression is missing. The wind at 153 mbar is from 270° at 71 kn.

The 77 group is for the level of maximum windspeed. The coding for this group requires only that values for pressure, wind direction, and windspeed be typed. In this example the data typed is recorded as Max wind data—77218 28100 43032. The level of maximum wind is 218 mbar and at that level the wind direction is from 280° at 100 kn. The last five digits—43032—are not important for the SSNAP program and can be omitted. Any missing data for the sounding is typed with slashes, as can be seen at the highest levels where the dew points cannot be calculated. Finally, if there has been a problem with the input of data or the surface data has not been input, a message will appear as follows.

ERROR

Data has been entered improperly, You must enter
mandatory level data (TTAAs) for SSNAP program to run
You must enter surface data for SSNAP to run
Strike any key to continue or to retype

An example of the final input chart after the TTAA data has been typed follows.

```

Input data in this form — TTAA YYGGI IIII
Time group and station ID — TTAA 65121 72357
Input in this form — PPP TTtDD ddfff
Surface data — 99966 18619 17010
1000 mbar data — 00053 ///// /////
925 mbar data — 92728 21804 19037
850 mbar data — 85465 20645 21521
700 mbar data — 70125 10065 25010
500 mbar data — 50583 07780 27020
400 mbar data — 40752 20780 26025
300 mbar data — 30958 37580 29039
250 mbar data — 25082 467// 28574
200 mbar data — 20226 571// 28573
150 mbar data — 15403 669// 27069
100 mbar data — 10650 675// 25540
Tropopause Data — 88153 671// 27071
Max wind data — 77218 28100 43032

```

After the mandatory level data has been entered, the prompts for significant temperature and dew-point data are displayed. The TTBB or significant temperature level data is easier to input. Remember, for each level the data is typed with a 00, 11, 22, 33... sequence. Only the pressure level, temperature data, and dew-point depression are needed to type the TTBB data. Significant level data (TTBB) as typed for Norman, Oklahoma, 15 June 1992 appears below.

```

TTBB 65120 72357 00966 18619 11938 18809 22925 21804 33910 23015
44863 20218 55833 23473 66828 23880 77658 04860 88650 04466
99638 06680 11359 26180 22286 40180-

```

The screen on your computer will look similar to the following.

Significant Level Data — TTBB Group

Please type over the letters with the appropriate data.

Hit return key after each data entry.

Format for TTBB is NNPPP TTtDD where NN is the group number,

PPP is pressure level, TTt is temperature, and DD is dew-point depression.

The values of NN are entered by computer—start typing with PPP

Format statement NNPPP TTtDD

```

Sig level data — 00966 18619
Sig level data — 11938 18809
Sig level data — 22925 21804
Sig level data — 33910 23015
Sig level data — 44863 20218
Sig level data — 55833 23473
Sig level data — 66828 23880
Sig level data — 77658 04860
Sig level data — 88650 04466
Sig level data — 99638 06680
Sig level data — 11359 26180
Sig level data — 22286 40180

```

Note that once you have typed the 99PPP TTtDD group, in this case 99638 06680, you can hit return and the sequence will start over at 11PPP TTtDD and continue until you have typed as many TTBB levels as you wish. While the data will disappear from the screen, it will be recorded by the computer. Hit RETURN twice after typing all the levels and start the significant level wind data.

The significant level wind data is the PPBB group. At the start of the PPBB group the program will print the following message.

Significant Level Wind Data — PPBB Group
Please type over the letters with the appropriate data.
When the code number appears on your screen, please
Type the wind levels you want in thousands of feet
You then will be asked to type the ddfff group in
The form that dd is the wind direction and fff is the
Windspeed. An example is 91246 where 9 is the code
And 12 represents winds at 12,000 ft, 4 means 14,000
Feet and 6 means 16,000 ft.

Sig level wind heights — 9hhhh

At this stage type the data. As an example, the Norman, Oklahoma, data from 15 June 1992 is used.

PPBB 65120 72357 90023 17010 18038 20035 90467 21028 23012
23012 91124 25512 24514 22015 9167/ 26015 27019 92025 27018
28025 26029 95012 26551 26536 24527-

When asked for significant level wind heights refer to the first group, which is the 90023 group. Then type the surface 2,000 and 3,000 ft winds in this first group. Type the "9" at the start of the code. Thus the first level is typed as 90023. Next the computer will return this line.

Sig level winds — ddfff ddfff ddfff

The values of both windspeed and wind direction should be typed for this first group. Since there are three heights in this initial group, type 17010 18038 20035 and then hit the return key. Once again you will be asked for the next group of heights.

Sig level wind heights — 9hhhh

Type in 90467 and the computer will ask for the significant level winds.

Sig level winds — 21028 23012 23012

Remember to leave a blank space between each of the three blocks of data in the line. Once you have completed all the data input, hit RETURN twice and the program will begin executing and will advance to the "output options menu" where you can view the skew T - log P diagram and other options from the sounding analysis program.

4.1.2 Enter Decoded Data by Hand--Data Input at Keyboard

The second way to enter a radiosonde report is to have one that is already decoded, for example, a hard copy of the temperature and wind profile. In this case enter a pressure level followed by the corresponding wind and temperature data. As an example, the data from 15 June 1992 is listed below with the TTAA's and TTBB's.

<u>Pressure</u> <u>(mbar)</u>	<u>Height</u> <u>(m)</u>	<u>Temp</u>	<u>Dew</u>	<u>Wind Dir</u>	<u>Windspeed</u>
966	362	18.6	16.7	170	10
1000	053	////	///	///	//
938		18.8	17.9		
925	728	21.8	21.4	190	37
910		23.0	21.5		
863		20.2	18.4		
850	1465	20.6	16.1	215	21
833		23.4	0.4		
828		23.8	-6.2		
700	3125	10.0	-5.0	250	10
658		4.8	-5.2		
650		4.4	-11.6		
638		6.6	-23.4		
500	5830	-7.7	-37.7	270	20
400	7520	-20.7	-50.7	260	25
359		-26.1	-56.1		
300	9580	-37.5	-67.5	290	39
286		-40.1	-70.1		
250	10820	-46.7	////	285	74
200	12260	-57.1	////	285	73
150	14030	-66.9	////	270	69
100	16500	-67.5	////	255	40

When you input the data, some quality control is performed here as values for each parameter are allowed to be entered only in realistic ranges. The ranges for the input parameters are as follows:

Pressure	[100 .. 1100 mbar]
Temperature	[-90 .. 50 deg C]
Dew point	[-90 .. 50 deg C]
Height	[0 .. 30,000 m]
Wind direction	[0 .. 360 deg]
Windspeed	[0 .. 250 kn].

These ranges represent measurements of the atmosphere up to about 100 mbar. The program will not accept input values outside of these prescribed limits. To use this method of data input, select the E option on the main input menu. The computer will respond with the following request.

Enter station name : Station Name_____

Type the name of the station being used and then the day number of the month.

Type over the date below if different

Enter day of month : [1..31]: ____

Type the day of the month of the data. There are limits from 1 through 31. Finally, type the time of the sounding that is being used.

Type over the previous time below if different

Enter the hour of data in UTC : [0000..2359]

This piece of data should be typed using four digits, for example, if the data is from 1200 UTC, type 1200 rather than 12. The limits cover a 24-h period. At this point type data for each individual pressure or height level that data is being used. It is vital that all data for the surface level be input properly.

Below is the first input request that appears on the computer screen.

Hit ESC key for missing data.

Hit RETURN key to continue.

Hit RETURN key at Pressure input to escape.

Pressure (mbar) [0.00..1100.00]: 0.00__

As an example, the surface data at Norman, Oklahoma, on 15 June 1992 is used here. The pressure at the surface is 966 mbar (remember that Norman is at 362 m above sea level). Type 966; you do not have to type the units such as millibars. Next type the surface temperature in degrees Celsius.

Hit ESC key for missing data.

Hit RETURN key to continue.

Hit RETURN key at Pressure input to escape.

Temperature (C)[-90.00..50.00]: -999.0

Simply type the value 18.6 for temperature to replace the -999.0 value listed originally. The next input is the dew-point temperature.

Hit ESC key for missing data.

Hit RETURN key to continue.

Hit RETURN key at Pressure input to escape.

Dew point (C)[-90.00..50.00]: -999.0

The surface dew point at Norman is 16.7°. Remember to type the actual dew point rather than dew-point depression. At higher levels, where dew point cannot be calculated, either press the ESC key to indicate that data is missing or just subtract 30.0° from the temperature. Another possibility is to type -90.0 °C, which will indicate that the moisture profile is as dry as allowed by the program limits.

Next you are asked for the height, which on this first level is the surface elevation at Norman. If you hit the ESC key the program will

assume that the height of the station is 0 m. The program will run and get useful results without the elevation, but the interpolation routine will be subject to error while calculating the heights. So while it is not mandatory to know the elevation, you will have more accurate results with the correct surface height level.

Hit ESC key for missing data.
Hit RETURN key to continue.
Hit RETURN key at Pressure input to escape.
Height (meters)[0.00..30000.00]: -999.00

At Norman, the surface height is 362 m. Type in the number 362 and hit the return key for the next input, which is the wind direction.

Hit ESC key for missing data.
Hit RETURN key to continue.
Hit RETURN key at Pressure input to escape.
Wind dir (deg)[0.00..360.00]: -999.0

The wind direction is in degrees from 0.00 to 360.00. In our example, the surface wind direction is 170°. The windspeed is 10 kn. Type this after the next return key is hit. Type calm winds with a 0 value. Any wind in excess of 250 kn in the sounding should be typed as 250, which is the maximum limit for the program.

Hit ESC key for missing data.
Hit RETURN key to continue.
Hit RETURN key at Pressure input to escape.
Windspeed (kn) [0.00..250.00]: -999.0

Once you have typed the surface values, continue to type the pressure or height levels (the program will take only 70 levels). If any data is missing, just hit the ESC key for that item and then continue with data input. The program is capable of interpolating any missing data. Thus, as an example, TTBB (significant temperature level data) gives only the pressure level, temperature, and dew-point data—the height, wind direction, and windspeed will be missing. Hit the ESC key for all the missing values and continue with the next level.

When you have finished typing the TTAA and TTBB data, input the PPBB (significant wind levels) in another sequence. Note that the TTAA and TTBB data are typed together, but the PPBB data are typed with a slightly different format. Once all the pressure level data has been input, hit the RETURN key to continue. The computer will display the following note:

Hit ESC for missing data
Hit RETURN key to continue input
Hit RETURN key at height input to finish
Height (feet)[-1.00..50000.00]: -1.00__

The following is a listing of the PPBB data from 15 June 1992 that can be typed using the format shown above.

<u>Height</u> <u>(ft)</u>	<u>Wind Direction</u> <u>(deg)</u>	<u>Windspeed</u> <u>(kn)</u>
Surface	170	10
2,000	180	38
3,000	200	35
4,000	210	28
6,000	230	12
7,000	230	12
11,000	255	12
12,000	245	14
14,000	220	15
16,000	260	15
17,000	270	19
20,000	270	18
22,000	280	25
25,000	260	29
50,000	265	51
51,000	265	36
52,000	245	27

Type the height level of the wind data in FEET. The limits are from 0 to 50,000 ft. Thus, for 12,000 ft, just type 12,000. Then continue by typing in the wind direction and windspeed.

```

Hit ESC for missing data
Hit RETURN key to continue input
Hit RETURN key at height input to finish
Height (feet) [-1.00..50000.00]: 12000
Wind dir (deg) [0.00..360.00]: 245
Windspeed (kn) [0.00..250.00]: 14

```

When the wind data has been input, hit RETURN at the height prompt and the SELECT OUTPUT OPTIONS MENU will be displayed.

4.1.3 Use Undecoded Data Stored on Disk

The third and final method of entering the radiosonde report does not need a coded or decoded radiosonde report. If the sounding data has been stored on a floppy disk and transferred to the microcomputer containing the sounding analysis program, then the user-specified station will be searched for and read.

Remember when using this method of data input, the TTAA data is to be placed in a separate file from the TTBB and PPBB data. Name your file in the following format.

Keep the TTAA data files on the hard drive or floppy drive in the following format: mmddytt.tta where mm is the month, dd is the day of the month, yy is the year, and tt is the time in UTC. As an example, the TTAA data for 15 June 1992 at 1200 UTC should be stored as 06159212.tta. The

second group of data, the TTBB data and PPBB are received together and should be kept in a file in the form mmddyytt.ttb or for 15 June 1992, 06159212.ttb. These two files will be joined as one in the program. If you choose the U option, the following computer notice appears and asks for the current month, date, year, and time.

Enter in Date and Time

Example 06159212 where 06 - month(mm), 15 - day(dd),
92 - year(yy), and 12 - time(tt in UTC)

Enter Month, Day, Year, and Time -->mmddyytt

Type in the value 06159212

After this, the appropriate station is selected from responses to two consecutive menus. The first menu allows you to select the section of the 48 contiguous states that contains the radiosonde data. The United States was divided into six different regions (aligned with the way the data is received). You can logically deduce the region of the country the RAOB station is located in from the list below.

Since soundings can be placed into the data base from all over the world, there is an option to choose the "Any Station" selection. If the "Any Station" option is used, you will be asked for the surface elevation at each station in addition to the latitude and longitude. Although it is not crucial, try to have the exact values for the best possible sounding results. If you respond to the "Any Station" option, type only the name of the city such as "Norman" (without the quotes) since the program searches only for the city name. Below is a list of the six regions into which the data is subdivided.

Select Region

Northeast
Southeast
Northcentral
Southcentral
Northwest
Southwest
Any Station

Select or ? for Help

If the date, city name, or station ID number is incorrectly typed, an error message will indicate that there is no TTAA data in the data base for that city or will indicate a number of other errors. Verify the date selected and try again. On some days, some stations may be missing and there will be no data available. If the wrong day is typed the data for that day will be incorrect. Be very careful to type in the correct data.

After you have selected one of the six regions of the country, another menu will appear that will show the RAOB sites available for that region; then select the appropriate city.

Northeast

Albany, NY
Buffalo, NY
Chatham, MA
Dulles Arpt, VA
Huntington, WV
Pittsburgh, PA
Atlantic City, NJ
Portland, ME
Caribou, ME

Southeast

Athens, GA
West Palm Beach, FL
Centerville, AL
Greensboro, NC
Charleston, SC
Wallops Island, VA
Jackson, MS
Key West, FL
Nashville, TN
Apalachicola, FL
Cape Hatteras, NC
Slidell, LA
Tampa Bay, FL
Waycross, GA

North Central

St Cloud, MN
Dayton, OH
Flint, MI
Green Bay, WI
Huron, SD
International Falls, MN
North Platte, NE
Omaha, NE
Peoria, IL
Rapid City, SD
Sault Ste Marie, MI

South Central

Amarillo, TX
Brownsville, TX
Corpus Christi, TX
Dodge City, KS
Longview, TX
Lake Charles, LA
Little Rock, AR
Midland, TX
Monett, MO
Norman, OK
Paducah, KY
Del Rio, TX
Stephenville, TX
Topeka, KS

Northwest

Boise, ID
Medford, OR
Glasgow, MT
Spokane, WA
Lander, WY
Salem, OR
Quillayute State, WA
Bismark, ND
Vandenberg AFB, CA

Southwest

Albuquerque, NM
Denver, CO
Grand Junction, CO
Winnemucca, NV
Salt Lake City, UT
Miramar NAS, CA
Mercury, NV
San Diego, CA
Tucson, AZ
Winslow, AZ
Ely, NV

On-line help is available for all menus in this program. When the cities are listed, the on-line help provides additional geographical information. The following example is for Norman, Oklahoma.

```
-----Help: Norman OK -----
|Norman Station Information|
|WMO ID #      72357      |
|Identifier    OUN        |
|Station Name  NORMAN     |
|State         OK US      |
|Latitude      35.23 N    |
|Longitude     97.47 W    |
|Elevation     362 Meters |
----- <space> to continue -----
```

Note that the geographical information is overlaid on the menu containing the list of cities. Hit the space bar using the help menu option to continue. After a site has been selected, a data file is read that contains the WMO 5-digit identifier for that station along with latitude, longitude, and station elevation. The program then searches for that identifier in a file containing the mandatory level radiosonde data—a convenient tool if all the 5-digit identifiers are unknown. The decoded mandatory and significant level data are combined into one data set that is sorted, duplications are removed, and layers above (in altitude) 100 mbar are discarded. As an example, after choosing the U option, choose "S" for the southcentral region of the country to get the Norman sounding. Once the southcentral menu appears, then choose "O" for NORMan, and the data for Norman, Oklahoma, will be available.

4.1.4 Retrieve a Sounding from a File

If a previously decoded sounding has been stored on the hard disk or on a floppy disk (see section 5.10), then it can be transmitted into the sounding analysis program. The data can then be edited or analyzed as before. Choose the R option on the menu to determine where the data was stored. The following question must be answered with either an "H" for hard disk or "A" or "B" for a floppy drive.

Retrieve from which drive: H)ard disk A)floppy B)floppy —>

Once the disk drive is selected, a menu will appear that will list the five available soundings on that disk.

```
-----Archived files-----
| 0 DENVER92 |
| 1 MIDLAND  |
| 2 OK052092 |
| 3 OKLAHOMA |
| 4 OMA0615  |
|            |
----- Select: -----
```

Recall that the names of each file cannot exceed eight characters. For the OKLAHOMA sounding, either move the cursor (or mouse) to number 3 or just type in choice 3. The computer will process the data, and the data will be available to use on the output options menu.

5. OUTPUT OPTIONS MENU

After the data has been entered into the sounding analysis program, several output options are available that primarily consist of displaying results in both alphanumeric and graphical format. In addition, the first option of the menu (section 5.1) allows quality control of the data before final results are obtained. Finally, the thunderstorm forecasting expert system can be executed from this menu. On-line help is available for the options on the menu by hitting a Shift and ? combination. The select output options menu is

Day is 15

Time is 1200 UTC

Station is NORMAN

```
-----Select Output Options-----
|
| Display/Edit Sounding Data
| Skew T-log P Diagram with Plotted Sounding
| Skew T-log P Diagram with Negative/Positive Areas
| Icing Profile
| List Icing Levels
| Plot Wind Profile
| Bar Charts of Sounding Parameters
| List Sounding Parameters
| List D-Values
| Write Current Sounding to a File
| Quit/Run Thunderstorm Expert System
|
|-----Select or ? for Help-----
```

5.1 Display and Edit Sounding Data

Regardless of the data entry method, the decoded sounding may be listed and edited. The sounding output will appear as seen below no matter which input method (D, E, U, or R) has been used. If this "D" option is selected, then the listing of the sounding data will appear as below. This data is for 15 June 1992.

LL	PRES	TEMP	DEW	HEIGHT	DIR/SPD	LL	PRES	TEMP	DEW	HEIGHT	DIR/SPD
36	100	-67.5		16500	255/40	13	700	10.0	-5	3115	250/10
35	111	-67.3		15824	245/27	12	786	19.5	-5	2138	230/12
34	123	-67.2		15221	265/51	11	815	22.5	-6	1831	230/12
33	150	-66.9		14023	270/69	10	828	23.8	-6	1689	220/15
32	153	-67.1		13903	270/71	9	833	23.4	0	1637	220/17
31	200	-57.1		12248	285/73	8	850	20.6	16	1463	215/21
30	218	-53.1		11698	280/100	7	863	20.2	18	1332	210/25
29	250	-46.7		10803	285/74	6	874	20.9	19	1220	210/28
28	286	-40.1	-70	9898	290/48	5	906	22.8	21	915	200/35
27	300	-37.5	-67	9570	290/39	4	910	23.0	21	875	200/35
26	359	-26.1	-56	8302	270/32	3	925	21.8	21	733	190/37
25	395	-21.4	-51	7613	260/29	2	938	18.8	17	610	180/38
24	400	-20.7	-50	7511	260/25	1	966	18.6	16	362	170/10
23	445	-14.4	-44	6707	280/25						
22	483	-9.7	-39	6092	270/18						
21	500	-7.7	-37	5820	270/20						
20	542	-3.0	-32	5186	270/19						
19	563	-0.7	-30	4884	260/15						
18	608	3.7	-26	4273	220/15						
17	638	6.6	-23	3875	235/14						
16	650	4.4	-11	3723	240/13						
15	658	4.8	-5	3623	245/13						
14	680	7.6	-5	3349	255/12						

Six different categories are listed here. The abbreviations listed are LL (level number), PRES (pressure level), TEMP (temperature), DEW (dew-point), HEIGHT (height of level), DIR (wind direction), and SPD (windspeed). Note that the format of windspeed is 170/10, where the wind is from 170° at 10 kn. There are 36 different levels of data (15 June 1992 at Norman, Oklahoma) on the chart, which was decoded from the TTAA, TTBB, and PPBB data and then formatted as seen above. The level number is listed first with the lowest pressure levels listed on the lower right corner of the table and continuing to the 100-mbar level on the left side of the table. Each pressure level, temperature, dew point, height (above sea level), wind direction, and windspeed is listed for the individual levels.

To change the data, hit the RETURN key, and the "Data Controls Options" menu will appear. It is possible to add a pressure level, delete a level, or change a level. Edit the data to correct an error or to change the profile of the atmosphere. The menu with the data quality control options is overlaid on the sounding data with a workspace below the dashed line. Values of parameters entered at the workspace are confined to the limits listed in section 4.1.2. They appear on the screen as follows:

LL	PRES	TEMP	DEW	HEIGHT	DIR/SPD	LL	PRES	TEMP	DEW	HEIGHT	DIR/SPD
36	100	-67.5		16500	255/40	13	700	10.0	-5	3115	250/10
35	111	-67.3		15824	245/27	12	786	19.5	-5	2138	230/12
34	123	-67.2		15221	265/51	11	815	22.5	-6	1831	230/12
33	150	-66.9								1689	220/15
32	153	-67.1								1637	220/17
31	200	-57.1								1463	215/21
30	218	-53.1								1332	210/25
29	250	-46.7								1220	210/28
28	286	-40.1								915	200/35
27	300	-37.5								875	200/35
26	359	-26.1								733	190/37
25	395	-21.4								610	180/38
24	400	-20.7								362	170/10
23	445	-14.4									
22	483	-9.7									
21	500	-7.7									
20	542	-3.0									
19	563	-0.7									
18	608	3.7									
17	638	6.6	-23	3875	235/14						
16	650	4.4	-11	3723	240/13						
15	658	4.8	-5	3623	245/13						
14	680	7.6	-5	3349	255/12						

Data Control Options

Add a level to the sounding

Change a level in the sounding

Erase a level in the sounding

View data behind menu

EXIT to previous menu

Select or ? for help

Quality control requires some meteorological expertise such as that of an SWO. However, with practice, you will be able to find any errors in the data and make the necessary corrections. For example, say at 700 mbar the temperature was improperly recorded as +20.0 °C rather than 10.0 °C, just select the "C" option for "Change a level in the sounding."

You will be asked which level number you wish to change.

LL	PRES	TEMP	DEW	HEIGHT	DIR/SPD	LL	PRES	TEMP	DEW	HEIGHT	DIR/SPD
36	100	-67.5		16500	255/40	13	700	10.0	-5	3115	250/10
35	111	-67.3		15824	245/27	12	786	19.5	-5	2138	230/12
34	123	-67.2		15221	265/51	11	815	22.5	-6	1831	230/12
33	150	-66.9								1689	220/15
32	153	-67.1								1637	220/17
31	200	-57.1								1463	215/21
30	218	-53.1								1332	210/25
29	250	-46.7								1220	210/28
28	286	-40.1								915	200/35
27	300	-37.5								875	200/35
26	359	-26.1								733	190/37
25	395	-21.4								610	180/38
24	400	-20.7								362	170/10
23	445	-14.4									
22	483	-9.7									
21	500	-7.7									
20	542	-3.0									
19	563	-0.7									
18	608	3.7									
17	638	6.6	-23	3875	235/14						
16	650	4.4	-11	3723	240/13						
15	658	4.8	-5	3623	245/13						
14	680	7.6	-5	3349	255/12						

Data Control Options

Add a level to the sounding
Change a level in the sounding
Erase a level in the sounding
View data behind menu
EXIT to previous menu

Enter 0 to Quit

Key in level to be changed [0..36]:0

Select or ? for help

Since the bad data is located at 700 mbar, which is level number 13 in the data, type the number 13. The pressure level will appear. However, if the temperature of 20.0 is incorrect, hit the RETURN key and the temperature of 20.0 will appear. Just type over that number with a 10.0 and hit RETURN. Since all other values are correct, hit RETURN for dew point, height, wind direction, and windspeed. Finally hit RETURN again and note that the program is "Processing sounding data." The corrected data will appear on the screen.

This method of data quality control is very helpful if incorrect data is typed while using the D or E option of data input or if bad data is acquired in the raw TTAA, TTBB, or PPBB data.

If an important level such as 500 mbar or an "interesting" level is missing from the data, that level can be added to the data. For example, to view the data at 399 mbar, on the Edit Menu select "A" for "Add a level to the sounding." When asked which level to add, in this case just type in 399 and then hit the ESCAPE key for the remaining variables. The data will be processed and the level requested will appear on the main data table.

If a level is to be deleted from the data set, just select the "E" option on the Data Control Options. The "E" option allows you to "Erase a level from the sounding." Select the level to be erased and then hit the RETURN key twice for the new results.

These data control options allow some flexibility in assembling a more accurate profile of the atmosphere.

5.2 Skew T - Log P Diagram with Plotted Sounding

View the skew T - log P diagram by choosing the "S" option. The temperature and dew points are plotted on a skew T - log P diagram similar to that shown in figure 1. This allows the vertical temperature and moisture profiles to be viewed.

An apparent shortcoming of this output is that the data in the lower portion of the troposphere is difficult to read because the pressure levels are so close together on the graphics screen. To compensate for this, you are allowed to choose which pressure level will be at the top of the screen. The possible levels are from 100 to 400 mbar, every 100 mbar.

Select Skew T Log P Diagram		
Display	Minimum pressure of 100 mbar	a Areas
Skew T 1	Minimum pressure of 200 mbar	
Skew T 1	Minimum pressure of 300 mbar	
Icing Pr	Minimum pressure of 400 mbar	
List Ici		
Plot Win		
Bar Char		
List sounding Parameters		
List D-Values		
Write Current Sounding to a File		
Quit/Run Thunderstorm Expert System		

Figure 2 shows a plot with the top of the screen at 400 mbar. Notice the improved readability of the data in the lowest portion of the troposphere.

5.3 Skew T - Log P Diagram with Positive/Negative Areas

The third option on the Output menu is the skew T - log P diagram with positive and negative areas shaded. Choose the "A" option or move the cursor or mouse to this option. The menu inside is similar to the menu that appears when choosing the "S" option for the skew T - log P. The advantage of using this option is demonstrated on the skew T - log P diagram. As a parcel is lifted on a skew T - log P diagram it is compared with the temperature profile. In those layers where the temperature of the parcel is less than the ambient atmosphere, the parcel is negatively buoyant (stable layers); where it is greater, positively buoyant (unstable layers). Figure 3 shows a case for Norman, Oklahoma, on 15 June 1992. The solid shaded areas show where the atmosphere is negatively buoyant or stable. Conversely, the dashed shaded regions are the area on the sounding where the atmosphere is positively buoyant or

unstable. For the Norman, Oklahoma, sounding of 15 June 1992, there is a stable region in the lower atmosphere with an unstable area above this region.

Day is 15 Time is 1200 UTC Station is NORMAN
Skew T - Log P

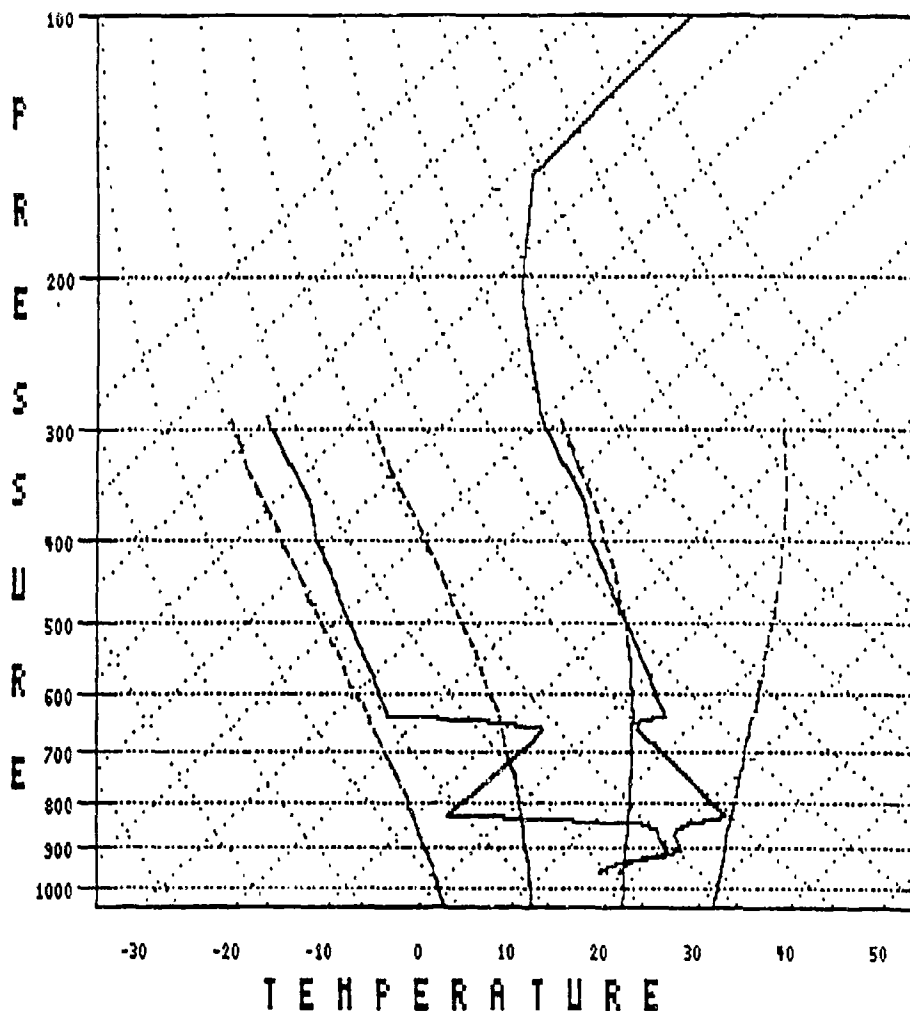


Figure 1. An example of a temperature (solid line) and dew-point (dashed line) profile plotted on a skew T - log P diagram. Isotherms (degrees Celsius) slant up towards the right. Isobars (millibars) are horizontal, and the dry-adiabats curve slightly as they slant up towards the left. Pseudo-adiabats and mixing ratio lines are not shown. Sounding is for Norman, Oklahoma, 15 June 1992, 1200 UTC.

Day is 15 Time is 1200 UTC Station is NORMAN
Skew T - Log P

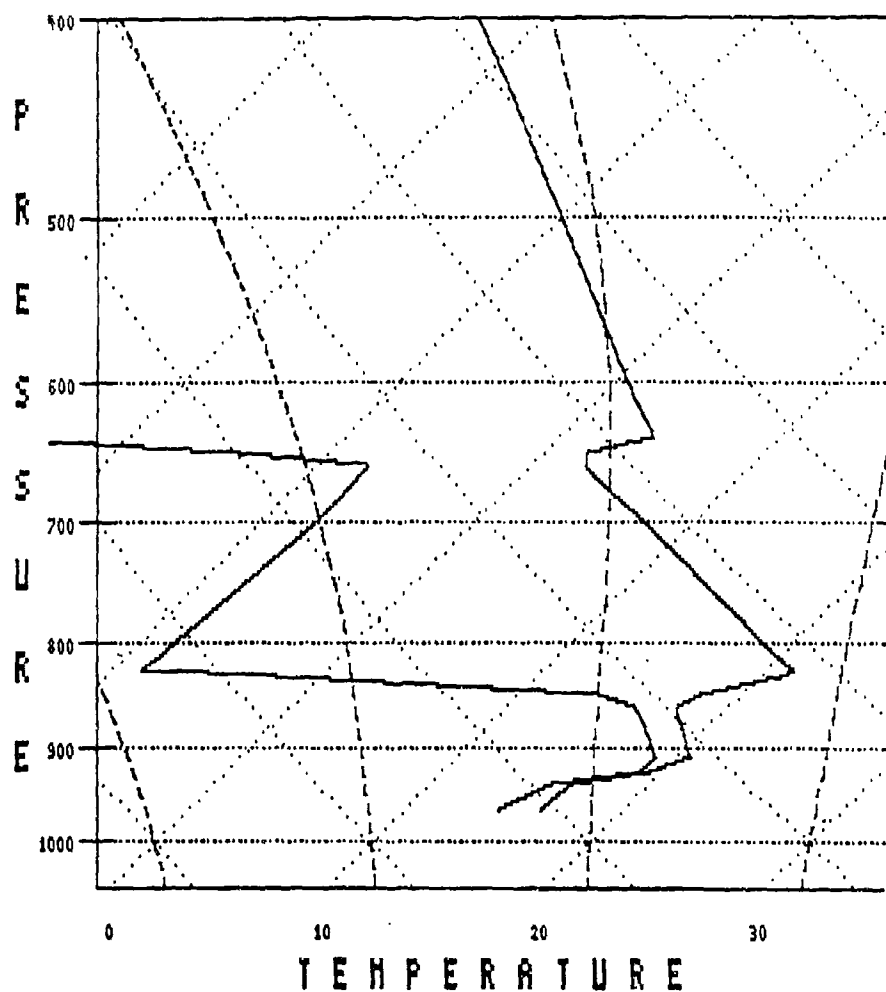


Figure 2. Same as for figure 1 except that the top of the chart is at 400 mbar.

Day is 15 Time is 1200 UTC Station is NORMAN
Skew T - Log P

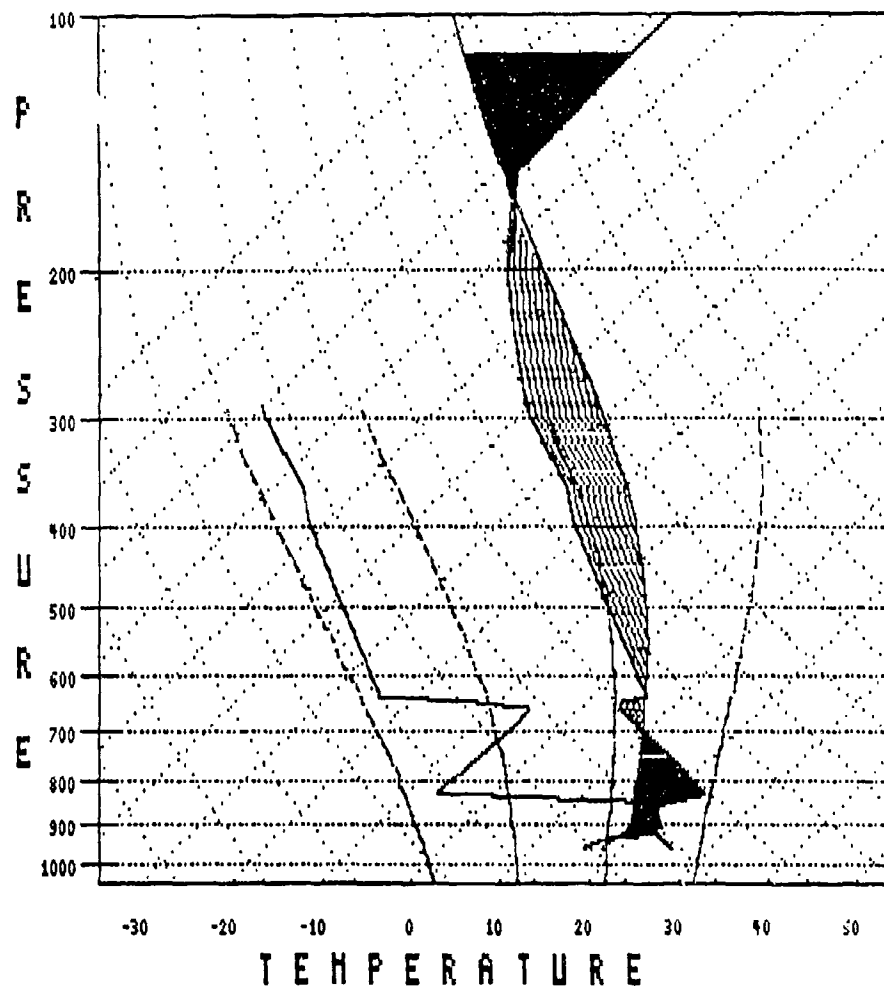


Figure 3. Skew T-log P diagram with shaded positive and negative temperature buoyancy areas. This example is the 1200 UTC sounding for Norman, Oklahoma, on 15 June 1992.

5.4 Icing Profile

Aircraft icing type and severity are calculated from the sounding data. The methodology is based on AWS/TR-80/001 (1980). Figure 4 shows the flow diagram that forms the foundation of the icing calculation. Because some of the branches of the decision tree are not readily derived from the sounding, you must supply these. They include the frontal type, precipitation type, and the type of thermal advection. A scheme (see section 7.6) to determine if layers of the sounding are conditionally unstable allows for automatic calculation of the cloud type. That is, if a layer is conditionally unstable, then cumuliform clouds are forecast; otherwise, stratiform clouds are the result. A change from the flow diagram of figure 4 is to allow icing to exist in layers that are conditionally unstable regardless of the initial dew-point depression. This is done if convection is anticipated. As seen in figure 5, bars are plotted when a particular icing type is expected within a layer. For Norman, Oklahoma, using the sounding data from 15 June 1992, there is no significant moisture in the middle and upper atmosphere that day. When the "I" option is selected on the output menu and then one of the anticipated weather types is chosen, the bar graph shows no areas of icing. Note that the determination of icing potential does not extend to as high a level as the skew T - log P plots temperature. This is because icing is not considered to be a serious problem when temperatures get below about -25 °C. In fact, the worst icing scenarios are found near the surface during freezing rain episodes.

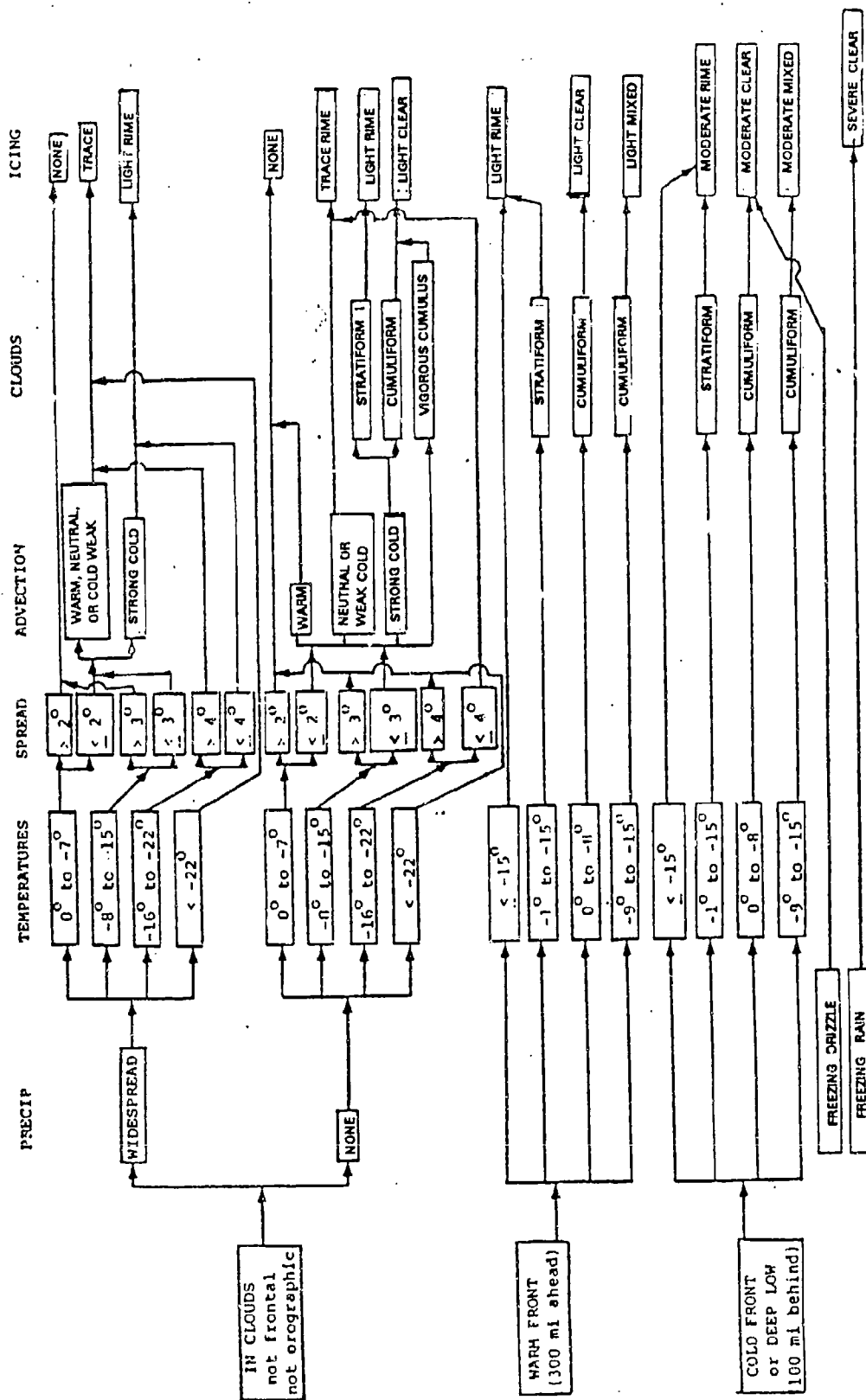


Figure 4. A flow diagram to assess aircraft icing potential (from AWS TR 80/001).

Day is 15 Time is 1200 UTC Station is NORMAN

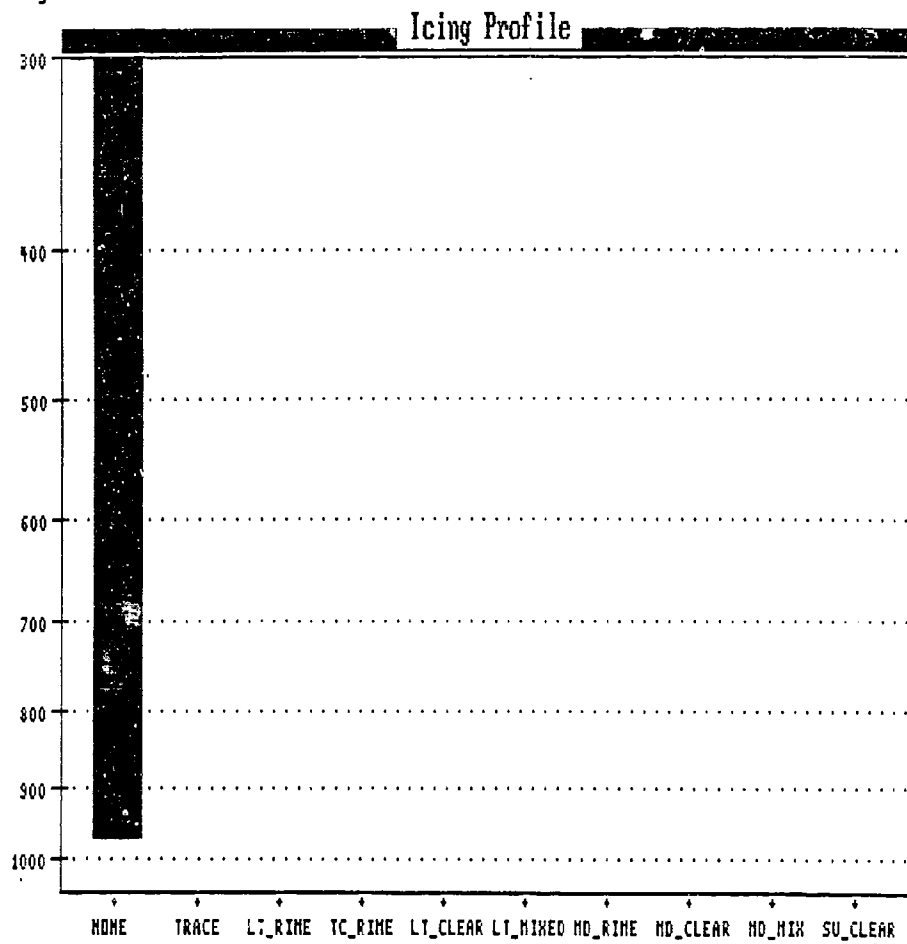


Figure 5. Output of various icing types and intensities for Norman, Oklahoma, sounding 15 June 1992.

5.5 List Icing Levels

A table of expected levels that may produce aircraft icing is another output option as follows. Use the "L" option on the output menu to see this table.

Day is 15				Time is 1200 UTC		Station is NORMAN	
LL	PRES	HT(M)	ICING TYPE	LL	PRES	HT(M)	ICING TYPE
36	100	16500	None	15	658	3623	None
35	111	15824	None	14	680	3349	None
34	123	15221	None	13	700	3115	None
33	150	14023	None	12	786	2138	None
32	153	13903	None	11	815	1831	None
31	200	12248	None	10	828	1689	None
30	218	11698	None	9	833	1637	None
29	250	10803	None	8	850	1463	None
28	286	9898	None	7	863	1332	None
27	300	9570	None	6	874	1220	None
26	359	8302	None	5	906	915	None
25	395	7613	None	4	910	875	None
24	400	7511	None	3	925	733	None
23	445	6707	None	2	938	610	None
22	483	6092	None	1	966	362	None
21	500	5820	None				
20	542	5186	None				
19	563	4884	None				
18	608	4273	None				
17	638	3875	None				
16	650	3723	None				

HIT RETURN TO EXIT

The height is in meters, the pressure in millibars, and the icing type can be any of the following: none, trace, light rime, trace rime, light clear, light rime, light clear, light mixed, moderate rime, moderate clear, moderate mixed, and severe clear.

5.6 Plot Wind Profile

A simple graphical output is used to display the vertical wind profile (figure 6). Not all of the levels in the sounding are plotted, as the output would become too cluttered to be readable. The vertical axis represents height above MSL. The winds are plotted in traditional notation where the full line segments are 10 kn, the half line segments are 5 kn, and the flags represent 50 kn. The flags and lines are directed toward the direction that the wind is blowing from. Due to space limitations in this PC-version of SSNAP, winds are displayed only to 30,000 ft MSL. As an example, using the "W" option from 15 June 1992, the lower level winds are from the south to southwest. Between 20,000 to 30,000 ft, the winds have increased to 25 to 30 kn with the wind from a westerly direction.

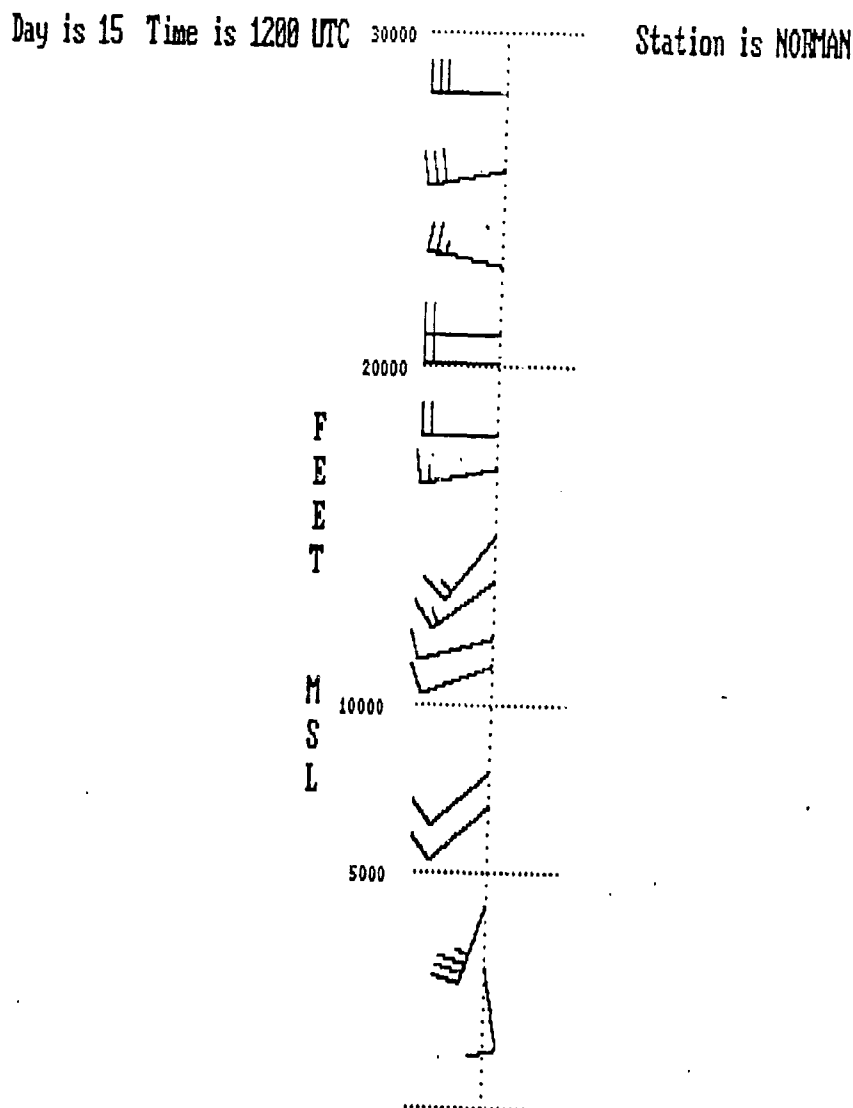


Figure 6. An example of vertical wind profile plot of speed (knots) and direction (degrees) for Norman, Oklahoma, 15 June 1992.

5.7 Bar Charts of Sounding Parameters

Various thermodynamic quantities including the stability indices are computed by the sounding analysis program. Eleven of these are plotted on the two bar charts of figure 7. The first chart plots out values for the following stability indices: K index (K), total totals (TT), Showalter index (SI), lifted index (LI), surface lifted index (SLI), and the severe weather threat index (SWEAT). Note that the listed value of the SWEAT index should be multiplied by 10 to get a true reading. For convenience it is plotted as a smaller value on the bar chart so that it can join the other indices on that chart. The numerical values appear above the bar chart for each variable. As an example, on 15 June 1992 the value of the SWEAT index is plotted as 43; however, the real value is 434. Details of the computation of these stability indices are provided in section 7.

The second chart displays five thermodynamic levels in millibars. These include convective condensation level (CCL), lifting condensation level (LCL), equilibrium level (EL), level of free convection (LFC), and the tropopause (TROP). With the exception of the TROP, which is extracted from the sounding data, details of the computation of these thermodynamic levels are provided in section 7.

Day is 15 Time is 1200 UTC Station is NORMAN
Thermodynamic graphics

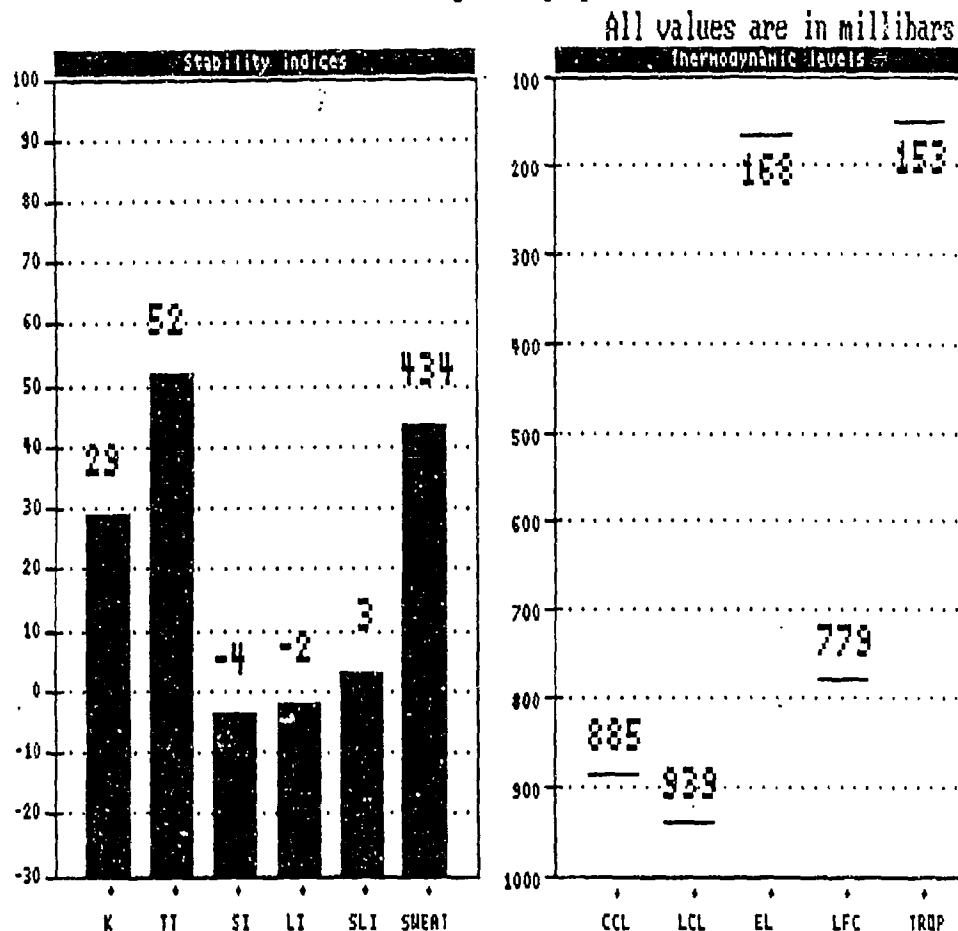


Figure 7. Bar charts depicting both the stability indices and computed thermodynamic levels. The SWEAT index had been divided by 10 in order to be scaled with the other parameters. The data is for the 1200 UTC sounding at Norman, Oklahoma, 15 June 1992.

5.8 List Sounding Parameters

Tabular results of the parameters plotted in section 5.7 plus some other computed quantities are given on two output screens. The first screen appears below:

Day is 15 Time is 1200 UTC Station is NORMAN
Sounding summary for NORMAN: Elevation = 362 m

The surface pressure is 966 mbar
Relative humidity at the sfc is 88%

The precipitable water is 1.08 in

Convective condensation level (CCL) = 885 mbar
Convective temperature = 27 °C

Lifting condensation level (LCL) = 939 mbar
Height of LCL 241 m or 790 ft
Temperature of LCL 289 K or 16 °C
Freezing Level is 14,501 ft AGL or 4421 m AGL

Level of free convection (LFC) = 779 mbar
Equilibrium level (EL) = 168 mbar

RETURN to continue...

The first screen gives information about the moisture content of the atmosphere as well as the height of various levels that involve convection. The second screen gives useful data concerning the TROP, the wind structure of the atmosphere, and many of the commonly derived stability indices.

Day is 15 Time is 1200 UTC Station is NORMAN
Sounding summary for NORMAN: Elevation = 362 m

The tropopause is at 153 mbar

The level of maximum winds is 218 mbar
The maximum wind is 100 kn from 280°
The mean speed of thunderstorms is 15 kn
Steering is 265°

STABILITY INDICES

K-index 29
Vertical totals 28
Cross totals 24
Total totals 52
Showalter stability index -4
Lifted index -2
Lifted index from CCL -3
Surface lifted index 3
Sweat index 434

RETURN to continue...

Details of these calculations are given in section 7.

5.9 List D-Values

The D-value at a given altitude is the actual height (in meters) of that altitude (MSL) minus the pressure altitude (the height of a standard atmosphere corresponding to the pressure at the actual altitude (Novlan 1982)). D-values are often useful for aviation purposes. The D-values are calculated for all sounding levels and are displayed in tabular form as in the following output example for Norman, Oklahoma, on 15 June 1992.

Day is 13		Time is 1200 UTC		Station is NORMAN			
PRES	HEIGHT	STDHEIGHT	DVALUE	PRES	HEIGHT	STDHEIGHT	DVALUE
	(m)	(m)	(m)		(m)	(m)	(m)
100	16500	15804	696	658	3623	3498	126
111	15824	15218	606	680	3349	3236	113
123	15221	14658	563	700	3115	3014	102
150	14023	13515	508	786	2138	2091	46
153	13903	13399	505	815	1831	1804	27
200	12248	11780	468	828	1689	1672	18
218	11698	11242	456	833	1637	1623	15
250	10803	10368	435	850	1463	1458	5
286	9898	9487	412	863	1332	1334	-2
300	9570	9168	402	874	1220	1227	-7
359	8302	7946	356	906	915	936	-21
395	7613	7287	327	910	875	898	-23
400	7511	7189	322	925	733	762	-29
445	6707	6421	286	938	610	643	-33
483	6092	5835	256	966	362	401	-39
500	5820	5577	243				
542	5187	4977	210				
563	4885	4691	194				
608	4274	4113	160				
638	3875	3737	138				
650	3723	3593	130				

HIT RETURN KEY TO CONTINUE

5.10 Write Current Sounding to a File

Once a sounding has been decoded and used, the data can be stored so that the computer does not have to decode it each time the data is needed. The sounding can be stored on any directory or subdirectory of the hard drive or floppy disks. To use this technique, choose the "C" option on the main output options menu. First, name the file in which the data will be stored. The file name can contain up to eight characters. Next, store the data, either on the hard disk or one of the floppy drives. As an example, you will name the file as follows.

Enter filename to store archived data --> XXXXXXXX.ARC

In this case name the file OKLAHOMA

Enter filename to store archived data --> OKLAHOMA.ARC

Then indicate on which drive or disk data is stored.

Archive to which drive: H)ard disk A)floppy B)floppy -->

Once this step is completed, the data can be assessed in future runs of SSNAP using the procedures described in section 4.1.4, the "retrieve a sounding from a file" choice on the main menu.

5.11 Quit/Run Thunderstorm Expert System

This option permits you to exit the output options menu and go to the next menu that will run TIPS (ARL's thunderstorm expert system).

6. THUNDERSTORM EXPERT SYSTEM SELECTION MENU

Once you have selected the Quit/Run Thunderstorm Expert system option on the "output options menu," the next menu appears as seen below.

This menu is called the "Thunderstorm Expert System Selection Menu."

```
-----Thunderstorm Expert System Selection Menu-----
|
|  eXit
|
|  Analyze sounding for a different station
|  Run thunderstorm forecast expert system
|
|----- Select or ? for Help -----|
```

6.1 Exit

This option allows you to exit the program and return to the directory or subdirectory being used.

6.2 Analyze Sounding for a Different Station

This option permits you to analyze another sounding for the current date or for any other date. The program will return to the main SSNAP menu where the D, E, U, and R input options were first introduced. Essentially, this selection allows for the entire cycle of data input and data output to begin again.

6.3 Run Thunderstorm Forecast Expert System

An expert system is a common artificial intelligence procedure used to solve problems (Parsaye and Chignell 1988). It relies on knowledge and reasoning to execute a task that is often performed by a human "expert." The knowledge base is a set of rules that is executed and implements a single operation.

Expert systems today are worthwhile as weather forecasting apparatuses since they provide expedient conclusions about the weather based on a large sum of data (Passner and Lee 1991). The ARL's thunderstorm expert system is called the TIPS. TIPS was synthesized using the "C" language integrated production system (CLIPS) programming language and is engineered as a "hands off" generalized expert system that can deliver thunderstorm forecasts at any location. TIPS uses several of the stability indices, precipitable water data, and the wind data from the sounding.

Under typical atmospheric conditions, available moisture and an unstable lapse rate are needed for thunderstorm formation. In many cases some mechanism to lift the moisture in unstable conditions is needed. TIPS models these essential meteorological assumptions and determines if thunderstorms are expected and if severe thunderstorms may also materialize.

To use this expert system, choose the "R" option on the thunderstorm expert system selection menu and TIPS will run with only one interruption. The program asks a single question as TIPS runs—whether there is a convective lifting mechanism present in the atmosphere. The answer can be "yes," "no," or "unknown," based on the weather situation expected at the station. At this time, recall that TIPS is really a short-term forecast or, in other words, a 12-h forecast for thunderstorms from the initial time of the sounding data. Tests have proved that TIPS is most effective using sounding data from 1200 UTC; however, data from any time of the day can be used for thunderstorm guidance.

Once the "lifting" question is answered, TIPS will produce an output that gives a worded forecast for thunderstorms and a list of some of the key weather parameters that were used to make the thunderstorm forecast and to determine whether the thunderstorms will become severe. As an example, the "lifting" question appears below.

Is there a significant lifting mechanism present ?

If moderate/strong lifting is expected from a cold front, a warm front, a convective outflow boundary, positive vorticity advection, orographic effects, or other localized conditions — Please answer with the word YES.

If significant subsidence is expected such as upper ridging or negative vorticity advection — Please answer with the word NO.

If you are uncertain about the lifting mechanism, have no data, or have limited time to check — Please answer UNKNOWN.

Answer with a complete word Yes, No, Unknown —>

A YES or NO answer is not necessary, and an UNKNOWN response is satisfactory; however, the answer should be typed correctly or the computer will respond with an error message. For example, if yse is typed instead of yes, the computer will respond with the following message:

```
41 rules fired
Run time is 8.84375 s
CLIPS>
```

If this occurs, type the following command: (exit). Note the parentheses are necessary for the program to respond. This will exit you from CLIPS, and you will have to start the program again with the SSNAP code word.

Another problem might occur when there is not enough memory space available on the RAM drive. Occasionally a statement may appear that says "Deallocating Memory," which means that the computer will be deallocating some memory space. This statement may appear when running the thunderstorm expert system. Most of the time it will not cause any problems, and the message will not interfere with the output. However, when running the expert system there may be a problem if there is not enough memory available on the RAM drive and the program will not execute. If this happens try a soft reboot of your PC and then run SSNAP again.

Assuming that the expert system runs with no errors, the output for 15 June 1992 at Norman, Oklahoma, will appear as follows.

At least one stability criterion is met and a lifting mechanism is present.

A thunderstorm with gusty winds and hail is expected; however, it is not expected to reach severe limits.

Input Variables:

Total Totals= 52 Cross Totals= 24 Vertical Totals= 28
Showalter Index= -4 Lifted Index= -2

Average Midlevel RH= 17% Wind Shear Score= 10
Precipitable Water= 1.08 in 500 mbar Windspeed= 20 kn
Sweat Index= 434 Low Level Jet Speed= 33 kn
Steering Speed of Thunderstorms= 15 kn

Type ex and hit RETURN to exit thunderstorm expert system and return to the sounding analysis program —>

The output for 15 June 1992 showed that thunderstorms were expected that day in the Norman area; however, they were not expected to reach severe levels.

The final step in running the expert system is to type the letters "EX" (without the quotes) to exit the program and return to the Thunderstorm Expert System Selection Menu, where you can either run TIPS again, select another sounding site, or exit the program.

7. SOUNDING ANALYSIS TECHNIQUES

7.1 Calculation of Thermodynamic Variables

This section describes background information on the calculation of stability indices and thermodynamic levels in the sounding analysis program. It is not vital to know these meteorological parameters to run SSNAP or TIPS; however, this section provides some knowledge of the physics involved in the program.

7.1.1 Vapor Pressure Calculation

This calculation uses a formula by Tetens:

$e_s = 6.11 \times 10^{a t / (b + t)}$, where t is in degrees Celsius and the constants a and b have the following values.

over water	$a = 7.5$	$b = 237.3$
over ice	$a = 9.5$	$b = 265.5$

7.1.2 Mixing Ratio and Saturation Mixing Ratio

$w = \frac{0.622e}{p - e}$ or $w = \frac{622e}{p - e}$, where p is the ambient pressure and e is the partial pressure due to the water vapor. Use the subscript s on e to denote the saturation mixing ratio.

7.1.3 Surface Relative Humidity

Surface relative humidity is calculated as $100 \times (w/w_s)$ where the surface relative humidity is the ratio of the mixing ratio to the saturation mixing ratio multiplied by 100 percent.

7.1.4 CCL

The CCL is the point of intersection of the temperature curve on the skew $T - \log P$ with the saturation mixing ratio line corresponding to the average mixing ratio in the surface layer (*Glossary of Meteorology*, 1959).

The CCL is determined by the following method. First, compute the average mixing ratio in the lowest 100 mbar of the sounding. Then interpolate between the two levels of the sounding such that the saturation mixing ratio at the higher (in altitude) level is less than the average mixing ratio and the saturation mixing ratio at the lower level. This is simply a technique to describe the intersection of the mean mixing ratio line with the temperature sounding. To find this point of intersection, use the following linear interpolation.

$$\left[\frac{w_s[I - 1] - w(\text{avg})}{w_s[I - 1] - w_s[I]} \right] * PP[I] + PP[I - 1] = \text{pressure of CCL},$$

where I is the higher level and $I - 1$ is the lower level.

The convective temperature is then found by bringing a parcel dry adiabatically from the CCL back down to the surface pressure. Poisson's equation is used to perform this calculation and is given by

$$T_{sfc} - T_{ccl}(P_{sfc}/P_{ccl})^{R/C_p},$$

where T_{sfc} is the convective temperature in degrees kelvin, T_{ccl} is the temperature in kelvin at the CCL, P_{sfc} is the surface pressure in millibars, P_{ccl} is the pressure in millibars at the CCL, R is the dry air gas constant, and C_p is the specific heat of air at constant pressure.

7.1.5 LCL

The LCL is the level to which a parcel of moist air must be lifted adiabatically before it becomes saturated with respect to water.

To get the height of the LCL, first compute the mean temperature between the initial level of the parcel and the LCL (based on pressure) and then use the formula

$$Z_{LCL} = (287.04 * (T_{BAR} + 273.16)/9.806) * \ln(P_0/PLCL).$$

The temperature of the LCL is calculated by plugging the temperature and dew point of the parcel at its initial level into the formula

$$TLCL = TD - (0.212 + 0.001571 * TD - 0.000436 * T) * (T - TD) + 273.16$$

and gives the answer in degrees kelvin.

The pressure of the LCL is given by one of two ways:

1. if $T = TLCL$ then $PLCL = P_0$ or
2. else $PLCL = P_0 * \frac{(TLCL)^{C_p/R}}{T_0}$

7.1.6 EL

The EL is often thought of as the level in the atmosphere where a rising parcel of air reaches a stable layer and can no longer rise above this layer. The EL is based on the temperature and pressure of the LCL. Thus it becomes obvious that the more unstable the conditions at the level of the LCL, the higher will be the EL level.

To determine the EL, calculate the equivalent saturated potential temperature for the parcel, which is given by

$$\theta(e) = \theta * \exp(XL * R/C_p * TL) \text{ where}$$

R - mixing ratio

XL - latent heat of condensation or sublimation based on whether the parcel is above or below freezing. This formulation may be suspect as the parcel may undergo a phase change from water to ice during ascent.

C_p - specific heat of air

TL - temperature at the LCL

θ - potential temperature, which uses a formula that takes into account water vapor

$$\theta = T * (1000/(p - e))^{R/C_p}.$$

Now compare $\theta(e)$ of the parcel with $\theta(e)$ for the sounding to determine the EL. Assume all points on the sounding are saturated, that is $T = T_w = T_d$. Start from the lowest pressure and compare the $\theta(e)$'s until $\theta(e)$ of the parcel is greater than $\theta(e)$ for the sounding. Then interpolate (pressure weighted average) to determine the pressure of the EL.

7.1.7 LFC

The LFC is found at the height at which a parcel of air lifted dry-adiabatically until saturated and saturation-adiabatically thereafter would first become warmer (less dense) than the surrounding air (*Glossary of Meteorology*, 1959).

7.1.8 Freezing Level

The freezing level is referred to the lowest level in the atmosphere at which air temperature 0°C is reached. Note that in some soundings the freezing level can be obtained in more than one instance such as a case where an inversion in the atmosphere exists.

7.1.9 TROP

This is the boundary between the troposphere and stratosphere and is often associated with a rapid change in the temperature and moisture curves on a skew $-T - \log P$ diagram. Typically, the atmosphere becomes more stable at this level and ranges from as high as 20 km in the tropics to 10 km in the polar areas. The meteorological values at the tropopause are given in the TTAA code.

7.2 Calculation of Stability Indices

To calculate the stability indices, you must know certain parameters at three mandatory levels.

- a. 850 mbar T, TD, FF, DD
- b. 700 mbar T, TD
- c. 500 mbar T, FF, DD

If data is not available at these three mandatory levels, then an interpolation scheme computes values for those levels without data. To interpolate, search through the sounding until a level is reached that has a lower pressure than the level of interest. When the appropriate condition is met, interpolation is mass-weighted as follows.

$$X = X[K] - (X[K] - X[K - 1]) * (F[K] - P) / (P[K] - P[K - 1]).$$

X can be T, TD, FF, DD. K is higher in altitude than K - 1. If a station is located at an altitude greater than 850 mbar, then those stability indices that depend on certain meteorological parameters at 850 mbar are not computed.

7.2.1 Calculation of the K index

$K = T_{850} - T_{500} + TD_{850} - (T_{700} - TD_{700})$. The subscripts refer to the pressure levels in millibars.

The K index is a good parameter for forecasting general nonsevere convection. Generally, when the K index begins to exceed 30, the atmosphere is warm and moist at low levels and relatively cold at 500 mbar. The K index is sensitive to the dew-point depression at 700 mbar and obtains a lower value when the relative humidity is low at 700 mbar. Supposedly, this can account for the detrimental effects of entrainment of dry air into the thunderstorm environment—a condition that is regarded to be favorable for the development of severe thunderstorms.

7.2.2 Calculation of Vertical Totals, Cross Totals, and Total Totals

vertical totals = $T_{850} - T_{500}$.

cross totals = $TD_{850} - T_{500}$.

total totals = vertical totals + cross totals.

The cross totals reveal the relationship between low-level moisture and the temperature at 500 mbar. Thus the higher the dew point at 850 mbar the higher the cross totals and subsequent increased chances for deep convection. Of course, for a given amount of low-level moisture, the colder the temperature at 500 mbar the higher the cross totals will be. In general for the U.S., a threshold value of 18 for the cross totals is considered necessary for convection.

The vertical totals are similar to the cross totals except that the 850-mbar air temperature is considered rather than the dew-point temperature. A threshold value of 26 has been used as a threshold value for deep convection.

A better parameter than using the cross and vertical totals is the total index, which is just the sum of the vertical and cross totals. A threshold value for the development of thunderstorms is around 44 and for severe and tornadic storms is above 50.

7.2.3 Calculation of the Showalter Stability Index

First calculate the LCL of a parcel at 850 mbar, and thus the temperature at the LCL by the following formula:

$TLCL = TD - (0.212 + 0.001571 * TD - 0.000436 * T) * (T - TD) + 273.16$
gives the answer in degrees kelvin.

The pressure of the LCL is given by

$$PLCL = 850 * \frac{(TLCL)^{C_p/R}}{T_{850} + 273.16}.$$

Next check if the LCL of the parcel at 850 mbar is above 500 mbar. If it is, then do not calculate the Showalter stability index. Then calculate the equivalent saturated potential temperature of the parcel using TLCL and PLCL.

$\theta(e) = \theta * \exp(XL * R/Cp * TL)$, where

R - mixing ratio

XL - latent heat of condensation or sublimation based on whether the parcel is above or below freezing. This formulation may be suspect as the parcel may undergo a phase change from water to ice during ascent.

Cp - specific heat of air

TL - temperature at the LCL

θ - potential temperature, which uses a formula that takes into account water vapor.

$\theta = T * (1000/(p - e))^{R/Cp}$.

Now set the 500-mbar temperature to -20 °C.

Allow an error tolerance of 0.05.

Set pressure level to 500 mbar.

Allow T increments of 5 °C.

Calculate a new $\theta(e)$ given T and 500 mbar and compare with $\theta(e)$ for the parcel to see if the new $\theta(e)$ is in tolerable limits—if not within 0.05, then add 5° to the temperature and recalculate $\theta(e)$ followed by a check of the error. Repeat until the error is less than 0.05 and then the Showalter index is $T_{500} - T_{guess}$.

If while incrementing by 5 °C the sign of the error has been reversed, then increment by half of the negative of the original increment.

7.2.4 Lifted Index

Use the mean temperature and mixing ratio previously computed for the lowest 100 mbar of the sounding. Then lift the mean temperature and dew point from 50 mbar above the surface. The temperature and pressure of the LCL are calculated by the usual formula and thus used to compute the equivalent saturated potential temperature. The same interpolation technique as above is used to compute the lifted index.

The lifted index compares the low-level heat and moisture with the 500-mbar temperature. It gives a measure of the buoyancy that a boundary layer parcel would have if it ascended moist adiabatically after reaching the LCL. The selection of the depth of the boundary layer varies from 3000 ft to a 100-mbar deep layer starting at the surface. The LI does not get degraded by dry air at 700 mbar, so it may be a better predictor of the occurrence of severe convection. Generally, a lifted index of -4 or lower warrants consideration of the potential for severe convection. More general convection can be expected for lifted index values slightly above 0.

7.2.5 Lifted Index from the CCL

This index is the same as the lifted index, except that it is calculated from the height of the CCL.

7.2.6 Surface Lifted Index

This index is the same as the lifted index, only use the surface temperature and mixing ratio and lift from there.

7.2.7 SWEAT Index

Calculate by (Miller 1972):

$$\text{SWEAT} = 12 * \text{TD}_{850} + 20 * (\text{Totals} - 49) + 2 * \text{FF}_{850} + \text{FF}_{500} + 125(\text{S} + 0.2),$$
where Totals refers to the total totals index and S is S_{500} (500 mbar - 850 mbar). The entire shear term, $125(\text{S} + 0.2)$, is set to zero if any of the following conditions are not met: 850 mbar wind direction in the range 130° through 250° ; 500 mbar wind direction in the range 210° through 310° ; 500 mbar wind direction minus 850 mbar wind direction positive; and both the 850- and 500-mbar windspeeds at least 15 kn. No term in the formula may be negative. The threshold for severe thunderstorms (a thunderstorm accompanied by gusts of at least 50 kn and/or hail at least 3/4-in in diameter) is a SWEAT index value of 300 and the threshold for tornadoes is a value of 400.

The SWEAT index is often used to assess the potential of thunderstorms becoming tornadic. The explanation of the terms used to calculate the SWEAT index provides insight into the usefulness. The first term suggests that good low-level moisture is necessary. The second term gets fairly large as the total totals increases above 50. This implies that stability is an important factor. Now the next three terms quantify the importance of strong low- and mid-level winds and the directional shear between them. The importance of the low-level jet is noted by the fact that the 850-mbar windspeed is multiplied by a factor of 2. Strong mid-level winds are also a necessary ingredient in the formation of severe and tornadic thunderstorms. Finally, directional shear allows the thunderstorm to have a longer lifetime by producing separate updraft and downdraft regions as opposed to having the downdraft replace the updrafts that produced the cell.

7.3 Wind Calculations

The wind calculations in SSNAP include the level of maximum winds: max wind at that level, mean speed of thunderstorms, and steering of thunderstorms. The first two products are derived from the TTAA data, while the speed of the thunderstorms and steering direction of the storms are calculated by using values of mid-level wind data (700 - 500 mbar).

7.4 Precipitable Water

The precipitable water will be expressed in inches. The procedure is simply to integrate the water vapor per unit area throughout the column up to 300 mbar.

7.5 D-Values

This module will compute the D-values for all observed pressure levels in the sounding. The D-value is defined to be the difference between the observed geopotential height and that associated with a standard

atmosphere. If surface pressures are assumed to be equal, then positive D-values are found, if by integration with respect to height, the actual atmosphere is warmer than the standard U.S. Atmosphere.

7.6 Conditionally Unstable Layers

Conditionally unstable layers are computed for input to the aircraft icing module of the sounding analysis program. The lapse rate within a layer is compared to the moist adiabatic lapse rate. If the ambient lapse rate is greater than the moist adiabatic, then the layer is tagged as being conditionally unstable; otherwise it is stable. This is done by calculating the equivalent saturated potential temperature at the top and bottom of the layer. If the equivalent saturated potential temperature is decreasing with height, then the layer is set to be conditionally unstable.

8. SUMMARY ON HOW TO USE SSNAP

8.1 Installing the Program

- a. Use either a 3-1/2-in or a 5-1/4-in floppy disk drive and transfer data to your hard drive. You can run SSNAP from the floppy disk.
- b. Ensure that the proper files are on your disk or SSNAP will not run.
- c. Type the word STARTME.
- d. Note the "Install SSNAP menu" that appears on your screen.
- e. Choose "Specify Directories" from this menu.
- f. Select driver directory, data directory, and program directory.
- g. Exit to MS-DOS.
- h. Type the word SSNAP at the prompt to run the program.

8.2 Input Options Menu

- a. D Option—decode a Rawinsonde Report.
 - (1) Name of station.
 - (a) Station name is not in the data base.
 - (b) Input elevation of station.
 - (c) Input latitude of station.
 - (d) Input longitude of station.
 - (b) If station name is in the data base the program continues.
 - (2) Input time group and station ID number—example, 65121 72357.
 - (3) TTAA data input.
 - (a) Input surface data.
 - (b) Input remaining mandatory data.
 - (4) TTBB data input.
 - (a) Input significant level data.
 - (b) Hit RETURN when done.
 - (5) PPBB data input.
 - (a) Input significant wind heights.
 - (b) Hit RETURN when done.
 - (6) Data Processed.
 - (7) The Select Output Options Menu should appear.
- b. E Option—Enter Decoded Data by Hand.
 - (1) Enter Station Name (choose any name you want).
 - (2) Enter Date (from 1 through 31).
 - (3) Enter Time of sounding (from 0000 through 2359).

- (4) Type surface pressure, temperature, dew point, height, wind direction, and windspeed. The program needs the surface data to run properly.
 - (5) Continue to type data to as many as 70 levels.
 - (6) If any data missing—use escape key.
 - (7) Height data allows you to enter PPBB data only.
 - (8) Hit RETURN when done and the Select Output Options Menu should appear.
- c. U Option— Use Undecoded Rawinsonde Data Stored on Disk.
- (1) Type in month, date, year, and time in the following format:
mmddyytt.
 - (2) Select region that station is in.
 - (a) Select sounding site from that region.
 - (b) The output options menu should appear.
 - (3) Select "Any Station" option rather than a "Region" option.
 - (a) Type name of Station.
 1. For station in data base—data processed and output options menu appears.
 2. For station not in data base.
 - Type in elevation of station.
 - Type in latitude of station.
 - Type in longitude of station.
 - Type in station five-number ID (example, 72357)
 - Data processed and output options menu appears.
- d. R Option—Retrieve a Sounding from a File.
- (1) Select the R option.
 - (2) Determine which disk drive or floppy drive you wish to retrieve data from.
 - (3) The Archive files menu should appear with a listing of available files.
 - (4) Select which sounding you wish to see.
 - (5) The computer should indicate that this sounding is being loaded into a file.
 - (6) The data output menu should appear on the screen next.

8.3 Select Output Options Menu

- a. Display/Edit Sounding Data.
- b. Skew T - log P Diagram with Plotted Sounding.
- c. Skew T - log P Diagram with Negative/Positive Areas.
- d. Icing Profile.
- e. List Icing Levels.
- f. Plot Wind Profile.
- g. Bar Charts of Sounding Parameters.
- h. List Sounding Parameters.
- i. List D-Values.
- j. Write Current Sounding to a File.
- k. Quit/Run Thunderstorm Expert System.
 - (1) Exit from program.
 - (2) Analyze another sounding from current date or any other date.
 - (3) Run thunderstorm forecast expert system.

- (a) Answer the lifting question.
 - Type (exit) if CLIPS> appears, which indicates that the user has made an error in response to lifting question.
- (b) Type ex to exit after expert system forecast is done.
- (c) Do a soft reboot of your computer if "deallocating memory" statement causes the expert system to fail in execution.

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